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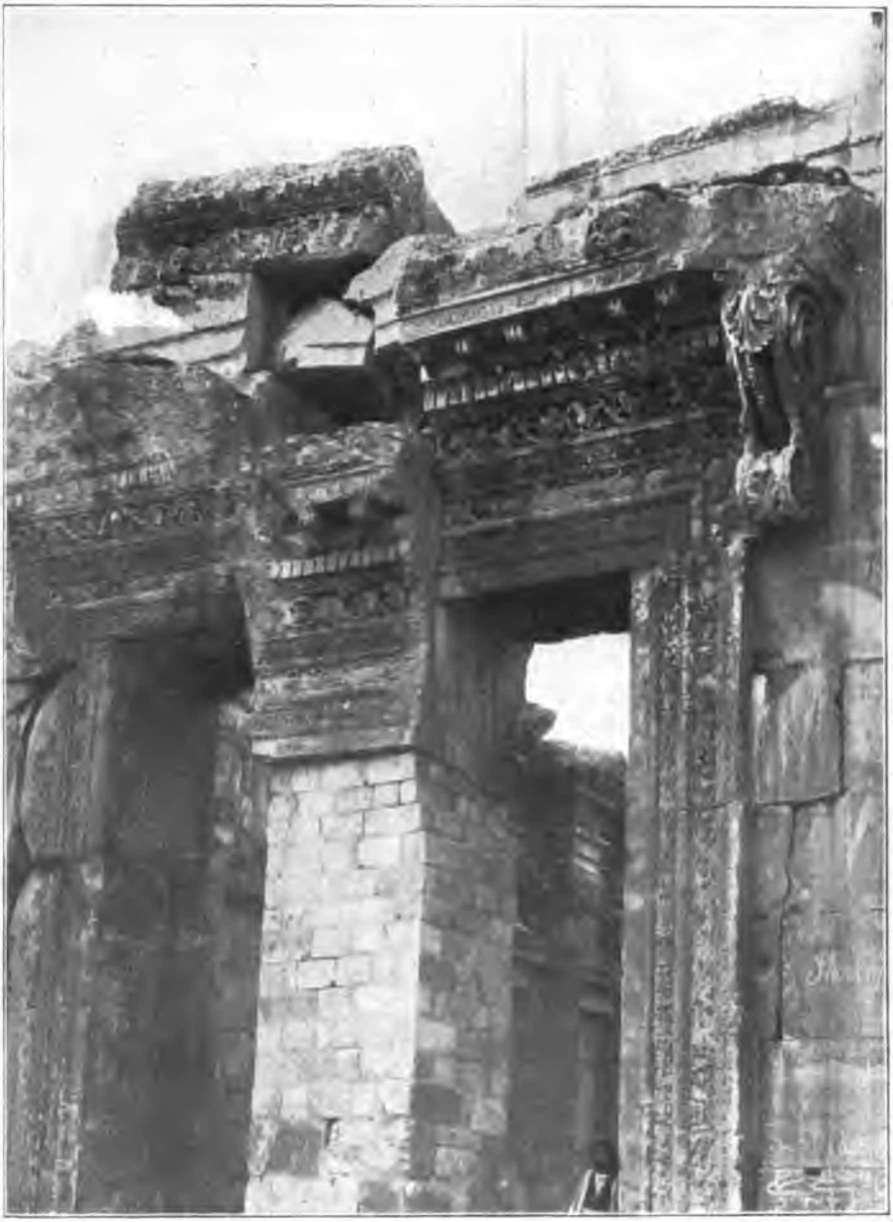

Roman Doorway.
From Corinthian Temple of Jupiter at Baalbec, Syria.

Cyclopedia
of
Drawing

A General Reference Work

ON DRAWING AND ALLIED SUBJECTS FOR ARCHITECTS, MECHANICAL
ENGINEERS, DRAFTSMEN, CARPENTERS, STONE CUTTERS,
SHEET METAL WORKERS, TEACHERS, STUDENTS,
AND ALL OTHERS INTERESTED IN DRAWING.

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SECRETARY, AMERICAN SCHOOL OF CORRESPONDENCE

Prepared especially for Practical Men by a Staff of

ARCHITECTS, DESIGNERS, AND EXPERTS OF ACKNOWLEDGED
PROFESSIONAL STANDING

FOUR VOLUMES

*One thousand seven hundred pages, two thousand illustrations,
tables and formulae*

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1907

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Foreword

THE Cyclopedia of Drawing has been prepared with the special object of giving the beginner and the self-taught practical man, a working knowledge of the principles which underlie all branches of drawing so he may know how to read and make drawings intelligently.

¶ The importance of drawing in the general plan of education is receiving wider and wider recognition. Few are the public schools which do not now teach it even in the primary departments. It is the universal language in which the peoples of all lands may communicate with each other,—and it is essentially the language of the architect and the engineer. Through it he communicates his noble designs, or his wonderful inventions, to his workmen for execution. As a cultural study drawing is of great value to every person who would lay any claim to a liberal education, teaching symmetry, beauty and exactness, and training the eye not only to see but to observe.

¶ A broad knowledge of drawing is therefore of vital importance to the draftsman, mechanic or young engineering student who is ambitious to advance in his chosen field. Unfortunately class room or even correspondence instruction is in many cases out of question, and thus many promising young men are left entirely without the means of gratifying their ambition.

¶ It is primarily for this class that the Cyclopedia of Drawing was published. It is based on the methods which the American School of Correspondence has developed and employed so successfully for many years in teaching drawing. It is compiled from the most valuable instruction papers of the School, selected, arranged and especially prepared for home study by a staff of experts and practical men, each an acknowledged authority in his specialty.

¶ The Cyclopedia has the unique advantage of having been revised and critically tested by actual use before being published, the individual instruction papers from which it is compiled having been studied and criticised by thousands of students in all parts of the world before being used in this work. In this way every obscure point, every small error so usual in technical books has been discovered and corrected and many valuable practical suggestions incorporated.

¶ Parts I and II are devoted to the subject of freehand and mechanical drawing; Part III to drawing for engineers and mechanics, and Part IV, to drawing for sheet metal workers.

¶ The work as a whole is intended to form an authoritative, handy reference work on the broad general subject of drawing, and we trust that it will be a valuable addition to the general as well as the technical library.

¶ Each section has been prepared by an authority on that particular subject, practicing architects, practical engineers, etc., teachers in the foremost engineering schools.

¶ Each section is profusely illustrated by drawings, sketches and valuable tables, especially prepared for this work, and at the end of each section there is an examination to test the reader's knowledge, thus combining the advantages of a text book with a reference book.

¶ The instruction papers comprising the various sections are presented in exactly the same form as they are used in actual instruction as the purpose of the work is to bring to men who cannot take a correspondence course some of the benefits of the American School of Correspondence instruction, and through them to acquaint the public with the method and high standing of its instruction.

¶ In conclusion grateful acknowledgment is due to the staff of authors and collaborators. Without the hearty co-operation of these men of wide experience and acknowledged ability, this work would have been impossible.

THIS VOLUME CONSISTS OF FOUR OF THE FIFTY REGULAR INSTRUCTION PAPERS IN THE ARCHITECTURAL COURSE OF THE AMERICAN SCHOOL OF CORRESPONDENCE. ARRANGED IN CONVENIENT FORM FOR READY REFERENCE BUT NOT IN THE ORDER USUALLY STUDIED.

THESE INSTRUCTION PAPERS ARE PREPARED BY ACKNOWLEDGED AUTHORITIES AND REPRESENT YEARS OF PREPARATION TO ADAPT THEM TO HOME STUDY.

THE INSTRUCTION PAPERS OF THE AMERICAN SCHOOL OF CORRESPONDENCE ARE NOT FOR SALE TO THE PUBLIC. THE PRESENT EXCEPTION IS MADE FOR THE PURPOSE OF ACQUAINTING PEOPLE INTERESTED IN DRAWING WITH THE THOROUGHNESS OF THE INSTRUCTION OFFERED, IN THE HOPE THAT THE OPPORTUNITY FOR PERSONAL EXAMINATION THUS OFFERED WILL LEAD THE READER TO CONTINUE HIS STUDIES IN THE SCHOOL.

ALTHOUGH REPRESENTING ONLY A SMALL PORTION OF THE COMPLETE COURSE, IT IS CONFIDENTLY BELIEVED THAT THIS VOLUME HAS SUFFICIENT MERIT IN ITSELF TO MAKE IT OF IMMEDIATE VALUE TO EVERYONE INTERESTED IN ANY FORM OF DRAWING.

EXAMINATION QUESTIONS

FOLLOWING EACH SECTION ARE THE QUESTIONS OR PLATES WHICH CONSTITUTE THE REGULAR EXAMINATION OF THE AMERICAN SCHOOL OF CORRESPONDENCE. THEY OFFER THE READER A MEANS OF TESTING HIS KNOWLEDGE OF THE SUBJECTS TREATED.

INABILITY TO ANSWER THESE QUESTIONS, OR TO SOLVE THE PROBLEMS, WILL SERVE TO SHOW THE NECESSITY FOR FURTHER STUDY.

THE READER IS URGED TO SOLVE EVERY PROBLEM, CHECKING HIS RESULTS WHEREVER POSSIBLE WITH SIMILAR PROBLEMS IN THE PRECEDING PAGES. THIS WILL AFFORD AN EXCELLENT MEANS FOR FIXING THE MATTER IN HIS MIND.

STUDENTS PREPARING FOR COLLEGE OR CIVIL SERVICE EXAMINATIONS WILL FIND THESE QUESTIONS OF GREAT VALUE.

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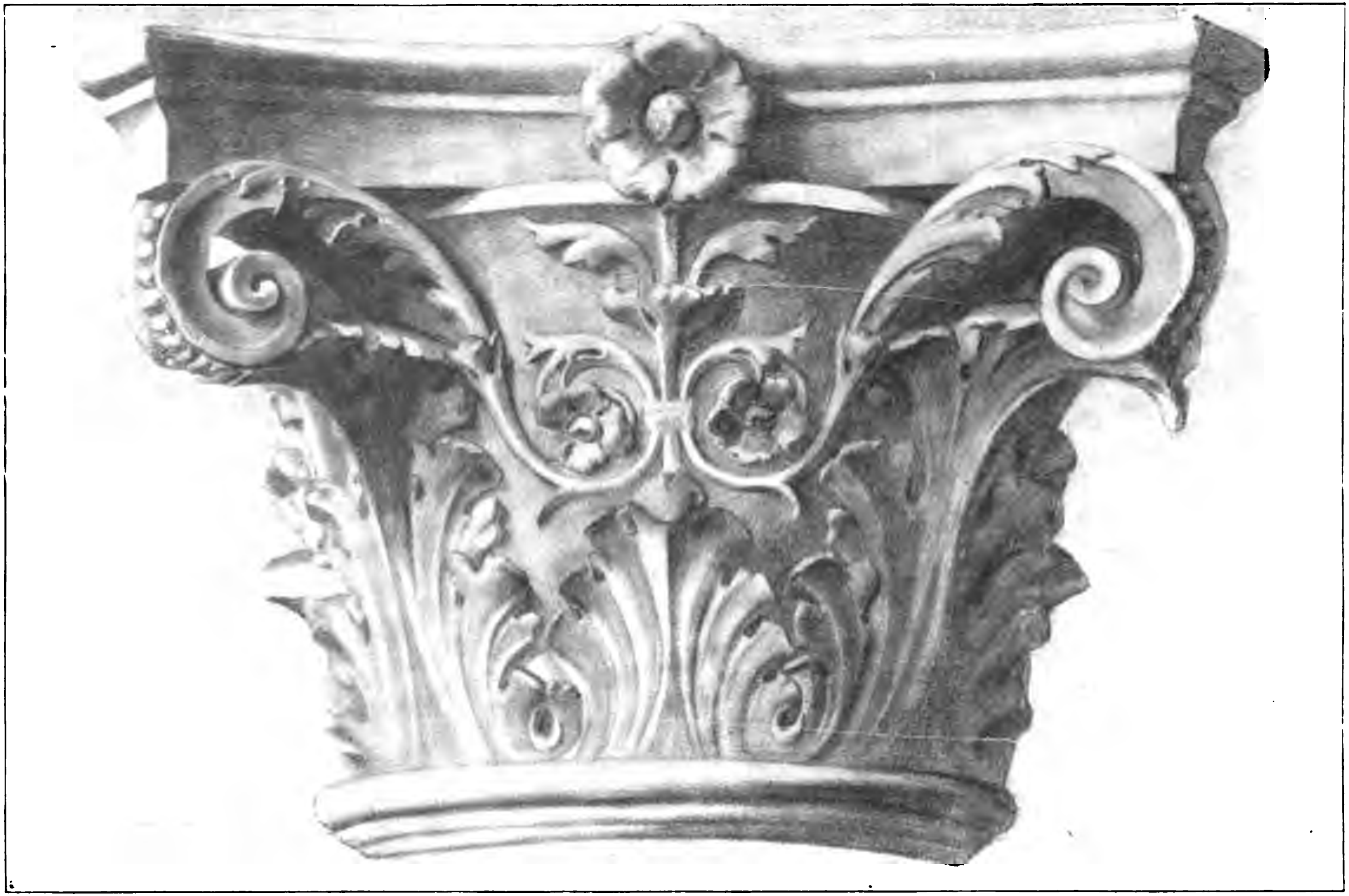

RENAISSANCE CAPITAL.
An example of charcoal drawing.

FREEHAND DRAWING.

1. The Value of Freehand Drawing to an Architect. Outside of its general educational value freehand drawing is as absolutely essential to the trained architect as it is to the professional painter. It is obviously necessary for the representation of all except the most geometric forms of ornament, and it is equally important in making any kind of a rapid sketch, either of a whole building or a detail, whether from nature or in the study of plans and elevations. It is perhaps not so generally understood that the training it gives in seeing and recording forms accurately, cultivates not only the feeling for relative proportions and shapes, but, also, that very important architectural faculty—the sense of the third dimension. The essential problem of most drawing is to express length, breadth, and thickness on a surface which has only length and breadth. As the architect works out on paper, which has only length and breadth, his designs for buildings which are to have length, breadth, and thickness, he is obliged to visualize; to see with the mind's eye the thickness of his forms. He must always keep in mind what the actual appearance will be. The study of freehand drawing from solid forms in teaching the representation on paper of their appearance, stimulates in the draughtsman his power of creating a mental vision of any solid. That is, drawing from solids educates that faculty by means of which an architect is able to imagine, before it is erected, the appearance of his building.

2. Definition of Drawing. A drawing is a statement of certain facts or truths by means of lines and tones. It is nothing more or less than an explanation. The best drawings are those in which the statement is most direct and simple; those in which the explanation is the clearest and the least confused by the introduction of irrelevant details.

A drawing never attempts to tell all the facts about the form depicted, and each person who makes a drawing selects not only the leading truths, but also includes those characteristics which appeal to him as an individual. The result is that no two people make drawings of the same subject exactly alike.

3. **The Eye and the Camera.** The question immediately arises: Why should we not draw all that we see; tell all that we know about our subject? Since the photograph does represent, with the exception of color, all that we see and even more, another question is raised: What is the essential difference between a photograph of an object and a drawing of an object? These are questions which bring us dangerously near the endless region of the philosophy of fine arts. Stated simply and broadly, art is a refuge invented by man as an escape from the innumerable and bewildering details of nature which weary the eye and mind when we attempt to grasp and comprehend them.

Without going into an explanation of the differences in structure between the lens of a camera and the lens of the eye, it may be accepted as a general statement that in spite of apparent errors of distortion the photograph gives us an exact reproduction of nature. Every minutest detail, every shadow of a shade, is presented as being of equal importance and interest, and it is easy to demonstrate that the camera sees much more detail than the human eye. In any good photograph of an interior the patterns on the walls and hangings, the carving and even the grain and texture of woods are all presented with equal clearness. In order to perceive any one of those details as clearly with the eye it would be necessary to focus the eye on that particular point, and while so focused all the other details of the room would appear blurred. The camera, on the contrary, while focused at one point sees all the others with almost equal clearness. This fact alone is enough to demonstrate the danger of assuming that the photograph is true to the facts of vision. Again, a photograph of an antique statue will exaggerate the importance of the weather stains and disfigurements at the expense of the subtle modelling of the muscular parts which the eye would instinctively perceive first.

Nature, then, and the photograph from nature, is a bewildering mass of detail. The artist is the man of trained perceptions who, by eliminating superfluous detail and grasping and presenting only the essential characteristics, produces a drawing in which we see the object in a simplified but nevertheless beautiful form.

In looking at the drawing we become conscious of the subject and its principal attributes; we comprehend and realize these with far less effort of the mind and eye than we should expend in taking in and comprehending the real object or a photograph of it. Compared to nature it is more restful and more easily understood, and the ease with which it is comprehended constitutes, the psychologists say, a large part of the pleasure we take in art; it certainly explains why we enjoy a drawing of an object when we may take no pleasure in the object itself, or a photograph of it.

4. **Restraint in Drawing.** The practical application of the preceding broad definition is neither difficult nor abstruse. The beginner in drawing usually finds his work swamped in a mass of detail, because his desire is to be absolutely truthful and accurate, and the more he has read Ruskin* and writers of his school the more does he feel that art and nature are one, and that the best drawing is that which most successfully reproduces nature with photographic fidelity. It may be taken for granted that a drawing must be true; true to nature. But truth is at best a relative term, and while it may be said that every normal eye sees practically the same, yet, after all, the eye sees only what it is trained to see. It is the purpose of all teaching of drawing to train the eye to see and the hand to put down the biggest and most important truths and to sacrifice small and unimportant details for the sake of giving greater emphasis or accent to the statement of the larger ones. "Art lives by sacrifices" is the expression of the French, the most artistic nation of modern times. The experience of the beginner is very practical testimony to the truth of the expression, for he very soon realizes that he has not the ability, even if it were best, to draw all he sees, and he has to face the question of what to leave out, what to sacrifice. Sense will tell him that he must at all costs retain those elements which have the most meaning or significance, or else his drawing will not be intelligible. So he is gradually taught to select the vital facts and make sure of them at least. It is true that the more accomplished the draughtsman becomes the greater will be his ability to successfully represent the lesser truths, the smaller details he sees,

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* NOTE.—Ample corroboration for all that is stated above may be found in Ruskin, but it is embedded in a mass of confusing and contradictory assertions. Ruskin is a very dangerous author for the beginner.

because having trained his perception to the importance of grasping the big truths he has also attained the knowledge and ability to express the smaller facts without obscuring the greater ones. Nevertheless the question of what to sacrifice remains one of the most important in all forms of representation. One of the commonest criticisms pronounced by artists on the work of their colleagues is that "he has not known when to stop"; the picture is overloaded and obscured with distracting detail.

5. Learning to See. It is very important that the student of drawing shall understand in the beginning that a very large part of his education consists in learning to see correctly. The power to see correctly and the manual skill to put down with accuracy what he sees—these he must acquire simultaneously. It is usually difficult at first to convince people that they do not naturally and without training see correctly. It is true, that there is formed in every normal eye the same image of an object if it is seen from the same position, but as minds differ in capacity and training, so will they perceive differently whatever is thrown upon the retina or mirror of the eye.

It is a matter of common observation that no two people agree in their description of an object, and where events are taking place rapidly in front of the eyes, as in a football game, one person with what we call quick perceptions, will see much more than another whose mind works more slowly; yet the same images were formed in the eyes of each. The person who understands the game sees infinitely more of its workings than one who does not, because he **knows what to look for;** and to draw with skill one must also know what to look for. Many people who have not studied drawing say they see the top of a circular table as a perfect circle in whatever position the eye may be in regard to the table. Others see a white water lily as pure white in color, whether it is in the subdued light of an interior or in full sunlight out of doors. In questions of color it is a matter of much study, even with persons of artistic gifts and training, to see that objects of one color appear under certain conditions to be quite a different color.

6. Outline. The untrained eye usually sees objects in outline filled in with their local color, that is, the color they appear to be when examined near the eye without strong light or shade thrown upon them. One of the first things the student has to learn is that there are no outlines in nature. Objects are distinguished from each other not by outlines but by planes of light and dark and color. Occasionally a plane of dark will be so narrow that it can only be represented by a line, but that does not refute the statement that outlines do not exist in nature. Very often only one part of an object will be detached from its surroundings. Some of its masses of light may fuse with the light parts of other forms or its shadows with surrounding shadows. If enough of the form is revealed to identify it, the eye unconsciously supplies the shapes which are not seen, and is satisfied. The beginner in drawing is usually not satisfied to represent it so, but draws definitely forms which he does not see simply because he knows they are there. Obviously then it is necessary to learn what we do not see as well as what we do.

7. Although there are no outlines in nature, most planes of light and shade have definite shapes which serve to explain the form of objects and these shapes all have contours, edges or boundaries where one tone stops and another begins. As the history of drawing shows, it has always been a convention of early and primitive races to represent these contours of objects by lines, omitting effects of light and shade. To most people to-day the outline of an object is its most important element—that by which it is most easily identified—and for a large class of explanatory drawings outlines without light and shade are sufficient. By varying the width and the tone of the outline it is even possible to suggest the solidity of forms and something of the play of light and shade and of texture.

8. Since, in order to represent light and shade, it is necessary to set off definite boundaries or areas and give them their proper size and contour, it follows that the study of outline may very well be considered a simple way of learning to draw, and a drawing in outline as one step in the production of the fully developed work in light and shade. An outline drawing is the simplest one which can be made, and by eliminating all questions of light and shade the student can concentrate all his effort on representing contours and proportions correctly. But he should always bear in mind that his drawing is a convention, that it is not as he actually

sees nature, and that it can but imperfectly convey impressions of the surfaces, quality and textures of objects.

9. It is often asserted that whoever can learn to write can learn to draw, but one may go further and assert that writing is drawing. Every letter in a written word is a drawing from memory of that letter. So that it may be assumed that every one who can write already knows something of drawing in outline, which is one reason why instruction in drawing may logically begin with the study of outline.

Some good teachers advocate the immediate study of light and shade, arguing that since objects in nature are not bounded by lines to represent them so it is not only false but teaches the student to see in lines instead of thinking of the solidity of objects. But these arguments are not sufficient to overbalance those in favor of beginning with outline, especially in a course planned for architectural students to whom expression in outline is of the first importance.

MATERIALS.

10. Pencils. Drawings may be made in "black and white" or in color. A black and white drawing is one in which there is no color and is made by using pencil, charcoal, crayon or paint which produces different tones of gray ranging from black to white.

The pencil is the natural medium of the architect and the materials for pencil drawing are very inexpensive and require little time for their preparation and care. Drawings in pencil are very easily changed and corrected if necessary. All the required plates for this course are to be executed in pencil.

The pencil will make a drawing with any degree of finish ranging from a rough outline sketch to the representation of all the light and shade of a complicated subject. In addition it is the easiest of all mediums to handle. Students are sometimes led to think that it is more artistic to draw in charcoal crayon or pen and ink. It may be that an additional interest is aroused in some students by working in these materials, but the beginner must assure himself at once that artistic merit lies wholly in the result and not at all in the material in which the work is executed.

Pencils are made in varying degrees of hardness. The softest is marked BBBBBB or 6B; 5B is slightly less soft and they increase in hardness through the following grades: 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H. A pencil should mark smoothly and be entirely free from grit. The presence of grit is easily recognized by the scratching of the pencil on the paper and by the unevenness in the width and tone of the line. The leads of the softer pencils are the weaker and are more easily broken. They give off their color the most freely and produce blackest lines. What hardness of pencils one should use depends upon a number of considerations, one of the most important being the quality of paper upon which the drawing is made.

Quick effects of light and shade can be best produced by the use of soft pencils because they give off the color so freely and the strokes blend so easily into flat tones.

A medium or hard pencil is necessary when a drawing is to be small in size and is intended to express details of form and construction rather than masses of light and shade. This is because the lines made by hard pencils are finer, and more clean and crisp than can be obtained by using soft grades. The smaller the drawing, the more expression of detail desired, the harder the pencil should be; a good general rule for all quick studies of effects of light and shade is to use as soft a pencil as is consistent with the size of the drawing and the surface of the paper. Beginners, however, are obliged to make many trial lines to obtain correct proportions, and in that way produce construction lines so heavy that the eraser required to remove them leaves the paper in a damaged condition. Until the student can draw fairly well he should begin every piece of work with a medium pencil and take care to make very light lines and especially to avoid indenting the paper.

It should be understood that pencil drawings ought never to be very large. There should always be a proportional relation between the size of a drawing and the medium which produces it. The point of a pencil is so small that to make a large drawing with it consumes a disproportionate amount of time. For large drawings, especially such showing light and shade, crayon or charcoal are the proper materials for they can be made to cover a large surface in a very short time. The larger the area to be covered the larger should be the point and the line producing it.

Special pencils with large leads can be obtained for making large pencil drawings.

11. **Paper.** In general the firmer the surface of the paper the harder the pencil one can use on it. For a medium or hard pencil the paper should be tough and rather smooth but never glazed. Many very cheap grades of paper, for example that on which newspapers are printed, take the pencil very well but have not a sufficiently tough surface to allow the use of the eraser. They are excellent for rapid sketches made very directly without alterations.

Paper for effects of light and shade should be soft and smooth. For this work the cheaper grades of paper are often more suitable than the expensive sorts. Paper with a rough surface should always be avoided in pencil drawings, as it gives a disagreeable "wooly" texture to the lines.

12. **Holding the Pencil.** Any hard and fast rules for the proper use of the pencil would be out of place, but until the student has worked out for himself the ways which are the easiest and best for him he cannot do better than adopt the following suggestions, which will certainly aid him in using the pencil with effect and dexterity.

The most important points in drawing are to be accurate and at the same time direct and free. Of course, accuracy—the ability to set down things in their right proportions—is indispensable; but the abilty to do this in the most straightforward way without constraint, fumbling, and erasures is also necessary. Art has been defined as the doing of any one thing supremely well.

The pencil should be held lightly between the thumb and forefinger three or four inches from the point, supported by the middle finger, with hand turned somewhat on its side.

There are three ways in which it is possible to move the pencil; with the fingers, the wrist, or the arm. Most people find it convenient to use the finger movement for drawing short, vertical lines. In order to produce a long line by this movement it is only necessary to make a succession of short lines with the ends touching each other but not overlapping, or by leaving the smallest possible space between the end of one line and the beginning of the next. The wrist movement produces a longer line and is used naturally to make horizontal lines. For a very long sweep of line the movement of the arm from the shoulder is necessary. This is, perhaps, the most difficult way of drawing for the beginner, but it affords the greatest freedom and sweep, and many teachers consider it the only proper method.

13. Position. The draughtsman should sit upright and not bend over his drawing, as that cramps the work and leads him to look, while working, at only a small portion of his drawing instead of comprehending the whole at a glance.

The surface to receive the drawing must be held at right angles to the direction in which it is seen, otherwise the drawing will be distorted by the foreshortening of the surface. A rectangular surface such as a sheet of paper is at right angles to the direction in which it is seen when all four corners are equally distant from the eye. A fairly accurate test may be made in the following manner: Locate the center of the paper by drawing the diagonals. Flat against this point place the unsharpened end of a pencil. Tip the surface until the length of the pencil disappears and only the point and sharpened end are visible, then the surface will be at right angles to a line drawn from the eye to its center. The pencil represents this line for a part of the distance because if properly held it is at right angles to the surface.

FIRST EXERCISES.

Before trying to draw any definite forms the student should practice diligently drawing straight lines in horizontal, vertical, and oblique positions, and also circles and ellipses.

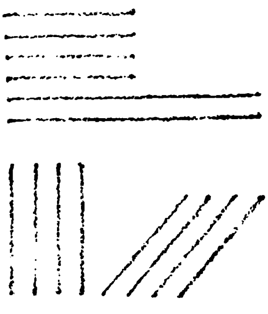

Fig. 1. Lines, Connecting Points.

14. Straight Lines. In drawing the straight line exercises points should first be placed lightly and the line drawn to connect them as in Fig. 1. Draw a series of ten or fifteen lines in each position, placing the points to be connected by the lines one inch apart and leaving a space of one quarter of an inch between each line. Next draw a series placing the points two inches apart, then a group with the points four inches apart, and finally a set which will give lines eight inches long. Start to draw vertical lines from the top, horizontal lines from the left to right, oblique lines which slant upward toward the right, from the lower point, and those slanting upward toward the left, from the upper point. Use all three pencils, 3H, F and a solid ink pencil for these exercises, and take the greatest care not to press too strongly on the paper with the harder grades. They are intended to make rather light gray lines. Where dark lines are desired always use the solid ink pencil. Try also making the exercises with different widths of line regulated by the bluntness of the point, and do at least one set using the solid ink pencil and making very wide lines as near together as is possible without fusing one line with another. In all of these exercises the lines should each be drawn with one pencil stroke without lifting the pencil from the paper and absolutely no corrections of the line should be made.

15. Circles and Ellipses. In practicing drawing circles start from a point at the left and move around toward the right as in Fig. 2. Draw a series of ten circles half an inch in diameter, forming each with a single pencil stroke. Next draw a group of ten with a one-inch diameter, still keeping to the single pencil stroke. Follow these with a set, each being two inches in diameter and another set with a three-inch diameter. In drawing these larger circles the free arm movement will be found necessary and the lines may be swept about a number of times for the purpose of correcting the first outline and giving practice in the arm movement. As the circles increase in diameter the difficulty of drawing them with accuracy by a single stroke increases also, but instead of erasing the faulty positions and laboriously patching the line, it is better to make the corrections as directed, by sweeping other lines about until a mass of lines is formed which gives the shape correctly. The single outline desired will be found somewhere within the mass of lines and may be accented with a darker line and the other trial lines erased.

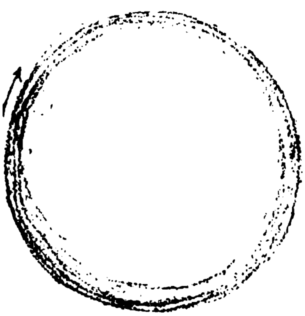

Fig. 2. Circles.

Draw a series of ten ellipses, Fig. 3, with a long diameter of half an inch, forming each with a single pencil stroke. Follow with a group of ten, having the long diameter one inch in length, joining each outline with a single pencil stroke. Proceed with a set having a long diameter of two inches and a set with a long diameter of three inches. Follow the same instructions for these last two groups as were laid down for drawing the larger circles, that is, sweep the lines about several times with the free arm movement.

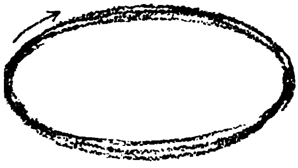
Fig. 3. Ellipses.

In drawing horizontal straight lines the elbow should be held close to the body. For vertical lines and for all curved lines the elbow should be held as far from the body as possible.

These exercises and similar ones of his own invention should be practiced by the student for a long period, even after he is studying more advanced work. Any piece of waste paper and any spare moments may be utilized for them. As in acquiring any form of manual skill, to learn to draw requires incessant practice, and these exercises correspond to the five-finger exercises which are such an important part of the training in instrumental music. While they are not very interesting in themselves the training they give to the muscles of the hand and arm is what enables the draughtsman to execute his work with rapidity, ease, and assurance.

The student should bear in mind that a straight freehand line ought not to look like a ruled line. A part of the attraction of freehand drawing, even of the simplest description, is the sensitive, live quality of the line. A straight line is defined in geometry as one whose direction is the same throughout, but slight deviations in a freehand straight line, which recover themselves and do not interfere with the general direction are legitimate, as the hand, even when highly trained, is not a machine, and logically should not attempt to do what can be performed with more mechanical perfection by instruments. Where freehand straight lines are used to indicate the boundaries of forms, the slight inevitable variations in the line are really more true to the facts of vision than a ruled line would be, inasmuch as the edges even of geometric solids appear softened and less rigid because they are affected by the play of light and by the intervening atmosphere.

This the beginner will not be able to see at first, for in this case as in so many others, his sight is biased by his knowledge of what the object is and how it feels.

16. Freehand Perspective. One of the chief difficulties in learning to draw is, as before stated, in learning to see correctly, because the appearance of objects so often contradicts what we know to be true of them. More than one beginner has drawn a handle on a mug because he knew it was there, regardless of the fact that the mug was turned in such a way that the handle was not visible. The changes which take place in the appearance of forms through changes in the position from which they are seen, are governed by the principles of perspective. Although students of this course are supposed to be familiar with the science of perspective, it is necessary to restate certain general principles of perspective with which the freehand draughtsman must be so familiar that he can apply them almost unconsciously as he draws. The most important of these are demonstrated in the following paragraphs, and their application should be so thoroughly understood that they become a part of the student's mental equipment. In theory the draughtsman draws what he sees, but practically he is guided by his knowledge as to how he sees.

The principles can be most clearly demonstrated through the study of certain typical geometric forms which are purposely stripped of all intellectual or sentimental interest, so that nothing shall divert the attention from the principles involved in their representation. The student will readily recognize the great variety of subjects to which the principles apply and the importance of working out the exercises and mastering them for the sake of the knowledge they impart. These principles can be explained very clearly by the use of the glass slate, which is a part of the required outfit for this course. All drawings should be made from the models in outline and in freehand on the glass, using the Cross pencil. The drawing should be tested and corrected according to the instructions for testing.

17. Tracing on the Slate. In beginning to study model drawing the model may be traced upon the slate held between the model and the eye and at right angles to the direction in which the object is seen. (See section 13.) In order to do this with accuracy it is absolutely necessary that the slate shall not move and it is equally necessary that the position of the eye shall not change. As neither of these conditions can be fulfilled exactly without mechanical contrivances for holding both the slate and the head fixed, it follows that the best tracing one can make will be only approximately correct and even that only if the object is of a very simple character. The more complicated the object the less satisfactory will be the tracing from it. Perhaps the best method is to mark the important angles and changes of direction in the contour with points and then rapidly connect the points with lines following the contours. Although the result may not be very correct, if carefully made the tracing will at least demonstrate the principal points wherein the appearance of an object differs from and contradicts the facts, and that is the sole object of the tracing. It awakens in the student the power of seeing accurately as it teaches the mind to accept the image in the eye as the true appearance of an object even if that image differs from the actual shape and proportion of the object as we know it by the sense of touch. *Except as it helps us to learn to see, the tracing gives no training in freehand drawing other than the slight manual exercise involved in drawing the line.*

18. Testing with the Slate. The great value of the slate for the beginner in freehand drawing is the ease with which the accuracy of a drawing may be tested. To obtain satisfactory results the models should be placed about a foot and a half in front of the spectator and the drawings made rather large. The drawing should be made freehand, in outline, and the greatest care taken to make it as accurate as possible before testing it because the object in making the drawing is to exercise the hand and eye. Drawing exercises should not be confounded with the preliminary exercises in tracing whose only object is to emphasize the fact that forms appear different as the position of the eye changes.

In order to test a drawing place the slate at right angles to a line from the eye to the model according to the directions in section 13. Holding the slate at this angle and keeping one eye closed move it backward and forward until the lines of the drawing cover the lines of the model. Any difference in the general direction of the lines or proportions can be readily observed. Corrections should not be made by tracing, but errors should be carefully noted and the alterations made freehand from a re-study of the models. If the drawing is too large to cover the lines of the model, errors may be discovered by testing the different angles of the drawing with those of the model. If all the angles coincide the drawing must be correct.

In making the tests the slate should be held firmly with both hands, and it cannot be emphasized too strongly that the test is of no value unless the slate is at right angles to the direction in which the model is seen. When groups of models or other complicated subjects are being tested only the directions of important lines and proportions of leading masses can be compared. It must be clearly understood that it takes some practice and much care to test the drawing of a simple form, and that the slate is not to be used as a means of tracing. The student will soon discover that it is impossible to trace any form or group having much detail or multiplication of parts owing to the impossibility of holding the slate and the eye for long in the same position at the same time.

Do not expect too much of the slate. Even the first exercises in tracing simple forms will show the student that unless he has acquired some facility in making lines freehand he cannot trace lines. Indeed it has often been observed that no one can trace who cannot draw. Another difficulty in using the slate at first is the resistance which the pencil encounters on the glass. It calls for a different pressure and touch from that used with a pencil on paper, so that the beginner is often discouraged unnecessarily and becomes impatient with the slate, partly because he expects too much from it and partly because he has not learned how to use it. Do not try to make perfect lines on the slate. Be satisfied at first to indicate the general direction of lines. Understand also that the slate is only to be used in beginning to draw. The student should as soon as possible emancipate himself from the use of the tests and depend upon the eye alone for judging the relations of proportions and lines. From the beginning a drawing should be corrected by the eye as far as possible before applying any tests.

FREEHAND PERSPECTIVE.[*]

19. The Horizon Line or Eye Level. This, as the name implies, is an imaginary horizontal line on a level with the eye. It is of great importance in representation, as all objects appear to change their shape as they are seen above or below the horizon line.

The following experiments should be made before beginning to draw any of the exercises in freehand perspective. Fasten two square tablets together at right angles to each other so that the adjacent corners exactly coincide, giving two sides of a cube. Hold it at arm's length with the edge where the two planes touch, parallel to the eyes and the upper plane level. Lower it as far as the arms allow, then raise it gradually to the height of the eyes, and above as far as possible, holding it as far out as possible. Observe that the level tablet appears to become narrower as it approaches the eye level, and when it is opposite the eye it becomes only a line showing the thickness of the cardboard. Observe that this line or front edge of the tablet always appears its actual length while the side edges have been gradually appearing to become shorter. As the tablet is lifted above the horizon the lower side begins to appear very narrow at first, but widening gradually the higher the tablet is lifted. It will be seen also that when the tablet is below the horizon line the side edges appear to run upward, and when the tablet is above the eye its side edges appear to run downward, toward the horizon.

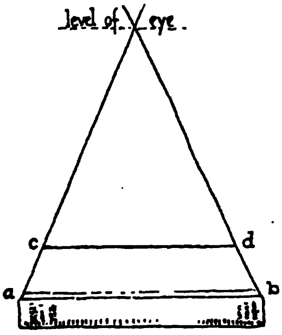

Fig. 4. Book with Strings.

That they and similar lines appear to converge and vanish in the horizon line is proved by the following experiment:

Place a book on a table about two feet away with its bound edge toward the spectator and exactly horizontal to the eye, that is, with either end equally distant from the eye. Between the cover and the first page and as near the back as possible place a string, leaving about two feet of it on either side. Hold the left end of the string in the right hand and move it until it coincides with or covers the left edge of the book. Hold the right end of the string in the left hand and move it until it covers the right edge of the book. The two strings will be seen to form two converging or vanishing lines which meet at a point on the level of the eye, that is, in the horizon line. This and the preceding experiment illustrate the following rule.

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[*] NOTE.—Through the courtesy of its author and publishers, these exercises in freehand perspective have been adopted from the text-book on "Freehand Drawing," by Anson K. Cross. Ginn & Co., Boston.

Rule 1. Horizontal retreating lines above the eye appear to descend or vanish downward, and horizontal retreating lines below the eye appear to ascend or vanish upward. The vanishing point of any set of parallel, retreating, horizontal lines is at the level of the eye.

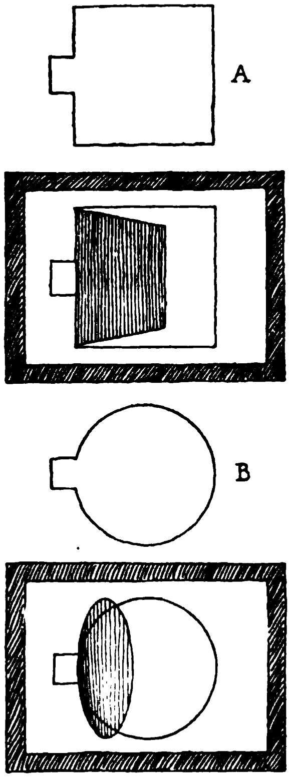

Fig. 5. Slates with Square and Circle Flaps.

It is necessary to remember that the horizon line is changed when the spectator's position is changed. This is very noticeable when one stands on a high hill and observes that the roof lines of houses which one is accustomed to see vanishing downward to the level of the eye, now vanish upward, since the eyes have been raised above the roofs.

Retreating lines are those which have one end nearer the eye than the other.

Exercise 1. Foreshortened Planes and Lines. Cut from paper a tracing of the square tablet, which is a part of the set of drawing models, and leave a projecting flap as at A, Fig. 5. Paste the flap on the under side of the slate, with the edges of the square parallel to the edges of the slate, and trace the actual shape of the square.

Holding the slate vertical and so that half the square is above and half below the level of the eye, turn the square somewhat away from the slate and trace the appearance. Turn it still farther and trace. Turn it so that the surface disappears and becomes a line.

Trace a circular tablet and cut it out of paper, leaving a flap as at B, Fig. 5. Paste the flap on the back of the slate, as with the square, and trace its real appearance. Turn the circle away at a moderate angle and trace its appearance. Trace it as it appears at a greater angle and finally place it so that it appears as a line.

Try similar experiments with the triangle, the pentagon, and the hexagon and observe that these exercises all show that lines and surfaces under certain conditions appear less than their true dimensions, and that this diminution takes place as soon as the surfaces are turned away from the glass slate.

When the square rests against the slate, with the centers of the square and slate coinciding, and the slate held so that half is above and half below the horizon line, all four corners of the square will be at equal distances from the eye so that a line from the eye to the center of the slate and of the square is at right angles to the surface of the slate, the latter represents in these experiments what in scientific perspective is called the picture plane. Thus a surface or plane appears its true relative dimensions only when it is at right angles to the direction in which it is seen.

It is for this reason that it is always necessary to arrange the surface on which a drawing is made, at right angles to the eye, otherwise the surface and drawing upon it become foreshortened; that is, they appear less than their true dimensions.

It is easy to see from the drawing of the foreshortened square in Fig. 4, that of the two equal and parallel lines *a b* and *c d* the nearer appears the longer, although neither of the lines are foreshortened as the respective ends of each are equally distant from the eye. This illustrates the following rule :

Rule 2. Of two equal and parallel lines, the nearer appears the longer.

Exercise 2. The Horizontal Circle. Hold the circular tablet horizontally and at the level of the eye. Observe that it appears a straight line.

Place the tablet horizontally on a pile of books about half way between the level of the eye and the level of the table. Trace the appearance upon the slate.

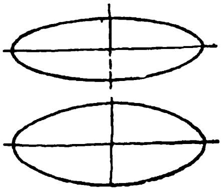

Fig. 6. Horizontal Circles.

Place the tablet on the table and trace its appearance.

While making both tracings the distance between the eye and the object, and the eye and the slate should be the same.

Hold the tablet at different heights above the level of the eye and observe that the ellipse widens as the height above the eye increases. These exercises illustrate the following rules:

Rule 3. A horizontal circle appears a horizontal straight line when it is at a level of the eye. When below or above this level the horizontal circle always appears an ellipse whose long axis is a horizontal line.

Rule 4. As the distance above or below the level of the eye increases the ellipse appears to widen. The short axis of any ellipse which represents a horizontal circle changes its length as the circle is raised or lowered. The long axis is always represented by practically the same length at whatever level the circle is seen.

Place the tablet on the table almost directly below the eye and trace its appearance.

Move it back to the farther edge of the table and trace it. It will be seen that where the level of the circle remains the same, its apparent width changes with the distance from the eye to the circle.

Exercise 3. Parallel Lines. Place the square tablet on the table 1½ feet from the front, so that its nearest edge appears horizontal; that is, so that it is at right angles to the direction in which it is seen. By tracing the appearance the following rules are illustrated:

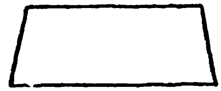
Fig. 7. Parallel Lines.

Rule 5. Parallel retreating edges appear to vanish, that is, to converge toward a point.

Rule 6. Parallel edges which are parallel to the slate, that is, at right angles to the direction at which they are seen, do not appear to converge, and any parallel edges whose ends are equally distant from the eye appear actually parallel.

Exercise 4. The Square. Place the square tablet as in Exercise 3, and it will be seen that two of the edges are not foreshortened but are represented by parallel horizontal lines. The others vanish at a point over the tablet on a level with the eye.

Now place the tablet so that its edges are not parallel to those of the desk and trace its appearance on the slate. None of its edges appear horizontal, and when the lines of the tracing are continued as far as the slate will allow, the fact that they all converge will be readily seen; the drawing illustrates the following rule:

Rule 7. When one line of a right angle vanishes toward the right, the other line vanishes toward the left.

The drawing also shows that the edges appear of unequal length and make unequal angles with a horizontal line and illustrates the following rule:

Rule 8. When two sides of a square retreat at unequal angles, the one which is more nearly parallel to the picture plane (the slate) appears the longer and more nearly horizontal.

Exercise 5. The Appearance of Equal Spaces on Any Line. Cut from paper a square of three inches and draw its diagonals. Place this square horizontally in the middle of the back of the table, with its edges parallel to those of the table, and then trace its appearance and its diagonals upon the slate. (Fig. 8.)

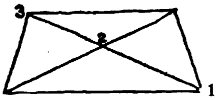

Fig. 8. Equal Space on any Line.

Note.— The diagonals of a square bisect each other and give the center of the square.

Compare the distance from the nearer end, 1, of either diagonal to the center of the square, 2, with that from the center of the square to the farther end of the diagonal, 3, for an illustration of the following rule:

Rule 9. Equal distances on any retreating line appear unequal, the nearer of any two appearing the longer.

Exercise 6. The Triangle. Draw upon an equilateral triangular tablet a line from an angle to the center of the opposite side. (This line is called an altitude.)

Connect the triangular tablet with the square tablet, and place them on the table so that the base of the triangle is foreshortened, and its altitude is vertical. Trace the triangle and its altitude upon the slate. The tracing illustrates the fact that the nearer half of a receding line appears longer than the farther half (see Rule 9), and also the following rule:

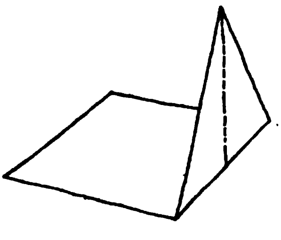

Fig. 9. The Triangle.

Rule 10. The upper angle of a vertical isosceles or equilateral triangle, whose base is horizontal, appears *in a vertical line erected at the perspective center of the base.*

Exercise 7. The Prism. Connect two square tablets by a rod to represent a cube, and hold the object so that one tablet only is visible, and discover that it must appear its real shape, A, Fig. 10. This illustrates the following rule:

Rule 11. When one face only of a prism is visible, it appears its real shape.

Place the cube represented by tablets (Fig. 10) in the middle of the back of the desk, and trace its appearance. First, when two faces only of the solid would be visible (B); and, second, when three faces would be seen (C). These tracings illustrate the following rule:

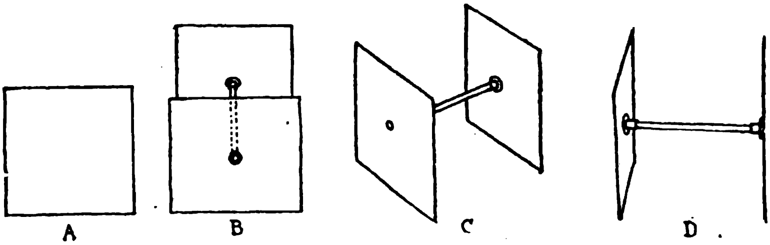

Fig. 10. The Prism.

Rule 12. When two or more faces of a cube are seen, none of them can appear their real shapes.

Place the cubical form on the desk, with the tablets vertical, and one of them seen edgewise (D) and discover that the other tablet does not appear a straight line. This illustrates the following rule:

Rule 13. Only one end of a prism can appear a straight line at any one time.

Exercise 8. The Cylinder. Connect two circular tablets by a 2½-inch stick, to represent the cylinder. Hold the object so that one end only is visible, and see that it appears a circle (Fig. 11).

Place the object on the table, so that its axis is horizontal but appears a vertical line, and trace its appearance. The tracing illustrates the following rule:

Rule 14. When an end and the curved surface of a cylinder are seen at the same time, the end must appear an ellipse (Fig. 12).

Place the object horizontally, and so that one end appears a vertical line, and trace to illustrate the following rule:

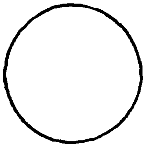

Fig. 11. The Cylinder—Circle.

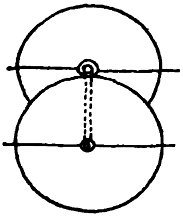

Fig. 12. The Cylinder—Axis Horizontal.

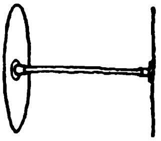

Fig. 13. The Cylinder—One End Straight Line.

Rule 15. When one end of a cylinder appears a straight line, the other appears an ellipse. (Fig. 13.)

Place the object upright on the table, and trace its ends and axis. Draw the long diameters of the ellipse, and discover that they are at right angles to the axis of the cylinder. This illustrates the following rule:

Rule 16. The bases of a vertical cylinder appear horizontal ellipses. The nearer base always appears the narrower ellipse. (Fig. 14.)

Place the object with its axis horizontal and at an angle, so that the surfaces of both tablets are visible. Trace the tablets and the rod, and then draw the long diameters of the ellipses, and discover that they are at right angles to the axis of the cylindrical form. The axes of the ellipses are inclined, and the drawing illustrates the following rules:

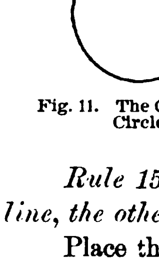

Fig. 14. The Cylinder—Upright.

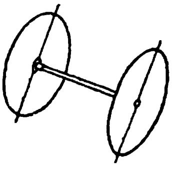

Fig. 15. The Cylinder—Axis Horizontal and at an Angle.

Rule 17. The bases of a cylinder appear ellipses, whose long diameters are at right angles to the axis of the cylinder, the nearer base appearing the narrower ellipse.

Note.—The farther end may appear narrower than the nearer, but must always appear proportionally a wider ellipse than the nearer end.

Rule 18. Vertical foreshortened circles below or above the level of the eye appear ellipses whose axes are not vertical lines.

Rule 19. The long axis of an ellipse representing a vertical circle below or above the level of the eye is at right angles to the axis of a cylinder of which the circle is an end.

Rule 20. The elements of the cylinder appear to converge in the direction of the invisible end. This convergence is not represented when the cylinder is vertical.

Note 1.—Less than half the curved surface of the cylinder is visible at any one time.

Note 2.—The elements of the cylinder appear tangent to the bases and must always be represented by straight lines tangent to the ellipses which represent the bases. When the elements converge, the tangent points are not in the long axes of the ellipses. See Fig. 12, in which if a straight line tangent to the ellipse be drawn, the tangent points will be found above the long axes of the ellipses.

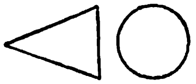

Fig. 16. The Cone.

Exercise 9. The Cone. Hold the cone so that its axis is directed toward the eye, and the cone appears a circle. Hold the cone so that its base appears a straight line, and it appears a triangle. (Fig. 16.)

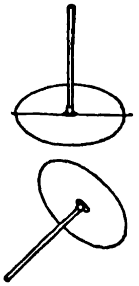

Fig. 17. The Cone—Tablet with Rod.

Place a circular tablet, Fig. 17, having a rod attached, to represent the axis of the cone, so that the axis is first vertical and second inclined. Trace both positions of the object, and discover that the appearance of the circle is the same as in the case of the cylinder. The tracings illustrate the following rule:

Rule 21. When the base of the cone appears an ellipse, the long axis of the ellipse is perpendicular to the axis of the cone.

Note 1.—More than half the curved surface of the cone will be seen when the vertex is nearer the eye than the base, and less than half will be seen when the base is nearer the eye than the vertex. The visible curved surface of the cone may range from all to none.

Note 2.—The contour elements of the cone are represented by straight lines tangent to the ellipse which represents the base, and the points of tangency are not in the long axis of this ellipse.

Exercise 10. The Regular Hexagon. In Fig. 18 the opposite sides are parallel and equal. The long diagonal A D is parallel to the sides B C and E F, and it is divided into four equal parts by the short diagonals B F and C E, and by the long diagonals B E or C F.

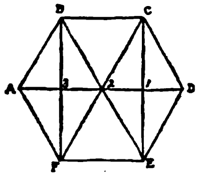

Fig. 18. Hexagon.

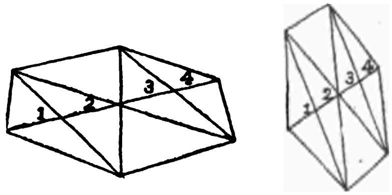

Fig. 19. Hexagon.

The perspective drawing of this figure will be corrected by giving the proper vanishing to the different sets of parallel lines, and by making the divisions on the diagonal A D perspectively equal.

Draw the long and short diagonals upon a large hexagonal tablet. Place this tablet in a horizontal or vertical position, Fig. 19, and then trace upon the slate its appearance and the lines upon it. The tracing illustrates the following rule:

Rule 22. In a correct drawing of the regular hexagon, any long diagonal when intersected by a long diagonal and two short diagonals, will be divided into four equal parts.

Exercise 11. The Center of the Ellipse Does Not Represent the Center of the Circle. Cut from paper a square of three inches, after having inscribed a circle in the square. Draw the diameters of the square and then place the square horizontally at the middle of the back of the table, with its edges parallel to those of the table. Trace the square, its diameters, and the inscribed circle, upon the slate. The circle appears an ellipse, and as the long axis of an ellipse bisects the short, it is evident that it must come below the

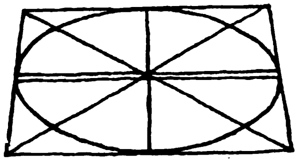

Fig. 20. Center of Circle not Center of Ellipse.

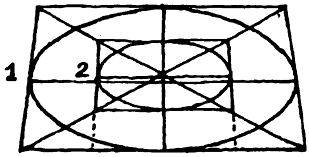

Fig. 21. Concentric Circles.

center of the square, and we discover that the center of the ellipse does not represent the center of the circle, and that the diameter of the circle appears shorter than a chord of the circle.

Exercise 12. Concentric Circles. Cut a 4-inch square from practice paper, and draw the diagonals. With the center of the square as center draw two concentric circles, 4 inches and 2 inches in diameter.

Place the card horizontally upon the table, as illustrated, and trace its appearance upon the slate, together with all the lines drawn upon it.

Draw the vertical line which is the short axis of both ellipses. Bisect the short axis of the outer ellipse, and draw the long axis of this ellipse. Bisect the short axis of the inner ellipse, and draw its long axis. It will be seen that the long axes are parallel but do not coincide, and that both are in front of the point which represents the center of the circles.

Each diameter of the larger circle is divided into four equal parts. The four equal spaces on the diameter which forms the short axis appear unequal, according to Rule 9. The diameter which is parallel to the long axes of the ellipses has four equal spaces upon it, and they appear equal. This diameter is behind the long axes, but generally a very short distance; and in practice, if the distance 1 2 between the ellipses measured on the long axis is one-fourth of the entire long axis, then the distance between the ellipses measured on the short axis must be a perspective fourth of the entire short axis. This illustrates the following rule:

Rule 23. Foreshortened concentric circles appear ellipses whose short axes coincide. The distance between the ellipses on the short axis is perspectively the same proportion of the entire short axis, as the distance between the ellipses measured on the long axis, is geometrically the same proportion of the entire long axis.

Exercise 13. Frames. In the frames are found regular concentric polygons with parallel sides, the angles of the inner polygons being in straight lines connecting the angles of the outer polygon with its center. In polygons having an even number of sides, the lines containing the angles of the polygons form diagonals of the figure, as in the square.

In polygons having an odd number of sides, the lines containing the angles of the polygon are perpendicular to the sides opposite the angles, as in the triangle.

Draw upon large triangular and square tablets the lines shown in Fig. 22. Place the tablets horizontally on the table, or support them vertically, and trace upon the slate the appearance of the edges and all the lines drawn upon them. The tracings illustrate the following rule:

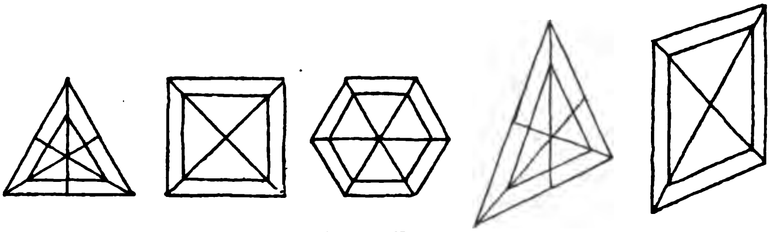

Fig. 22. Frames.

Rule 24. In representing the regular frames, the angles of the inner figure must be in straight lines passing from the angles of the outer figure to the center. These lines are altitudes or diagonals of the polygons.

20. After making the tracings described in the foregoing exercises, draw (not trace) freehand on the slate the various tablets, arranged to illustrate each one of the exercises. This is really drawing from objects, and where the rods are used to connect the tablets the figures are equivalent to geometric solids. After the proportions of the surfaces are correctly indicated, lines connecting the corresponding corners of the tablets should be drawn to complete the representation of solid figures. The lines indicating the rods and those lines which in a solid form would naturally be invisible, may be erased. By the use of the three rods of different lengths, three figures of similar character but different proportions may be obtained. These should each be drawn, but each in a different position.

The following directions, which are based on general principles, apply to all drawing whether from objects or from the flat, for work in pencil or in any other medium; drawing from another drawing, a photograph or a print, whether at the same size or larger, is called working from the flat.

21. General Directions for Drawing Objects. First observe carefully the whole mass of the object, its general proportions and the direction of lines as well as the width of the angles. Then sketch the outlines rapidly with very light lines, and take care that all corrections are made, not by erasing but by lightly drawing new lines as in Fig. 23. By working in this manner much time is saved and the drawing gains in freedom. Where the drawing is kept down to only one line which is corrected by erasure, the line becomes hard and wiry, and there is a tendency to be satisfied with something inaccurate rather than erase a line which has taken much time to produce. There is always a difficulty at first in drawing lines light enough, and it is well for the beginner to make the first trial lines with a rather hard pencil. Practice until the habit of sketching lines lightly is fixed. The ideal is to be able to set down exact proportions at the first touch. This, however, is attained by comparatively few artists, and only after long study, but the student will soon find himself able to obtain correct proportions with only a few corrections.

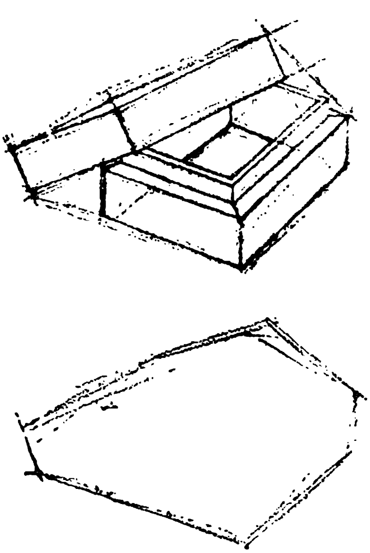

Fig. 23. Blocking in Trial Lines.

22. It cannot be too strongly emphasized that the student must teach himself to regard the subject he is depicting, as a whole, and to put down at once lines that suggest the outline of the whole. This he will find contrary to his inclination, which with the beginner is always to work out carefully one part of the drawing before suggesting the whole.

There are two objections to this; in the first place, much time having been spent on one part, it is almost inevitable that the addition of other portions reveals faults in the completed part, and unnecessary time is consumed in correcting. The second objection is that a drawing made piecemeal is sure to have a disjointed look, even if the details are fairly accurate in their relative proportions.

The idea of unity is lost and some one detail is apt to assume undue importance, instead of all details being subordinated to the general effect of the whole. It is always most important to state the general truths about the subject rather than small particular truths, which impair the general statement. This applies particularly to small variations in the outline which should be omitted until the big general direction or shape has been established.

23. Where an outline drawing is desired, after the correct lines have been found, they should be made stronger than the others and then all trial lines erased. In doing this the eraser will usually remove much of the sharpness of the correct lines so that only a faint indication of the desired result remains. These should be strengthened again with a softer pencil and each line produced, as far as possible, directly with one touch ; in the case of curves and very long lines, breaking the line and beginning a new one as near as possible to the end of the previous line, but taking care that the lines do not lap.

As soon as the student has acquired some proficiency in drawing the single figures made from the tablets, groups of two or three objects should be attempted. Combinations of books or boxes with simple shapes, or vases, tumblers, bowls and bottles will illustrate most of the principles involved in freehand perspective. Outline sketches may be made on the slate first and tested in the usual way, and afterward the same group may be drawn larger on paper. The chief difficulty in drawing a group is to obtain the relative proportions of the different objects. There is the same objection to completing one object and then another as there is to drawing a single object in parts. The whole group must be suggested at once. This can best be done by what is called blocking in, by lines which pass only through the principal points of the group. The block drawing gives hardly more than the relative height and width of the entire group and the general direction of its most important lines. But if these are correct, the subdivision of the area within into correct proportions is not difficult. The longer and more important lines of the parts are indicated and short lines and details lost.

24. Testing Drawings by Measurement. In drawings which are not made on the slate the following method of testing proportions is usual. With the arm stretched forward to its greatest length, hold the pencil upright so that its unsharpened end is at the top. Move it until this end coincides with the uppermost point of the object. Holding it fixed and resting the thumb against the pencil, move the thumb up and down until the thumb nail marks the lowest point of the object. The distance measured off on the pencil represents the upright dimension. Holding the pencil at exactly the same distance from the eye, turn it until it is horizontal and the end of the pencil covers the extreme left point of the object. Should the height and width be equal, the thumb nail would cover the extreme right edge of the object. If the width is greater than the height, use the height as a unit of measurement and discover the number of times it is contained in the width. Always use the shorter dimension as the unit of measurement. The accuracy of the test demands that the pencil should be at exactly the same distance from the eye while comparing the width and height. In order to insure this, the arm must not be bent at the elbow and must be stretched as far as possible without turning the body, which must not move during the operation. The distance from the eye to the object must not change during the test, and the position of the eye and body is first fixed by leaning the shoulders firmly against the back of the chair and keeping them in that position while the test is taking place. It is equally important in both the upright and horizontal measurement that the pencil be held exactly at right angles to the direction in which the object is seen; *i.e.*, at right angles to an imaginary line from the eye to the center of the object. In either position the two ends of the pencil will be equally distant from the eye. The test should be made several times in order to insure accuracy, as there is sure to be some slight variation in the distances each time. Avoid taking measurements of minor dimensions, as the shorter the distances measured the more inaccurate the test becomes. At the best measurements obtained in this way are only approximately correct, and too much care cannot be taken in order to render the test of use. Applied carelessly, the test is not only valueless, but thoroughly misleading. When there is any great conflict between the appearance of the object and the drawing after it has been corrected by the test, it is often safe to assume some mistake in applying the test and to trust the eye. In such a case the test may be tested by the use of the slate. A few lines and points will be sufficient to indicate the width and height on the slate, and the relative proportions can then be calculated.

The plumb-line affords another method of testing. A thread or a string with any small object for a weight attached to one end, is sufficient. Hold the string so that it hangs vertical and motionless, and at the same time covers some important point in the object. By looking up and down the line the points directly over and under the given point can be determined and the relative distances of other important points to the right and left can be calculated. The plumb-line will also determine all the vertical lines in the object and help to determine divergence of lines from the vertical.

A ruler, a long rod, or pencil held in a perfectly horizontal position is also of assistance in determining the width of angles and divergences of lines from the horizontal.

25. Misuse of Tests. The use of tests may easily be perverted and become mischievous. Since the object of all drawing is to train the hand and eye, it follows naturally that the more the student relies upon tests the less will he depend upon his perceptions to set him right, and the less education will he be giving to his perceptions. There is no greater mistake for a student than to use the measuring test before making a drawing. Spend any amount of time in calculating relative proportions by the eye, but put these down and correct them by the eye, not once but many times before resorting to tests. All the real education in drawing takes place before the tests are made. Let the student remember that the tests may help him to make an accurate drawing, but they will never make him an accurate draftsman in the true sense. Nothing but training the eye to see and the hand to execute what the eye sees, will do that. When the student has reached the end of his knowledge, has corrected by the eye as far as he can, then by applying tests he is enabled to see how far his perceptions have been incorrect. That is the only educational value of the test. Merely to make an accurate drawing with as little mental effort as possible, relying upon test measurements, requires considerable practice and skill in making the tests, but gives very little practice or training in drawing.

26. Light and Shade. Objects in nature, as before explained, detach themselves from each other by their differences in color and in light and shade.

In drawing without color, artists have always allowed themselves a very wide range in the amount of light and shade employed, extending from drawing in pure outline up to the representation of exact light and shade, or of **true values,** as it is called.

Drawings which contain light and shade may be divided into two classes: Form drawing, which is from the point of view of the draftsman, and value drawing, which is from the point of view of the painter.

27. Form Drawing. In form drawing the chief aim, as the name implies, is to express form and not color and texture. In order to do this, shadows and cast shadows are indicated only as far as they help to express the shape. This is the kind of drawing practiced by most of the early Italian masters, and it has been called the Florentine method. It is often a matter of careful outline with just enough shadow included to give a correct general impression of the object. There is usually little variety in the shadow and no subtle graduations of tone, but the shadows are indicated with sufficient exactness of shape to describe the form clearly. Form drawing is a method of recording the principal facts of form with rapidity and ease and of necessity deals only with large general truths. Perhaps its most distinguishing feature is that it does not attempt to suggest the color of the form.

28. Value Drawing. The word value as it is used in drawing is a translation from the French word *valeur*, and as used by artists it refers to the relations of light and dark.

Value drawing represents objects exactly as we see them in nature; that is, not as outline, but as masses of lights and darks. In value drawing the artist reproduces with absolute truth the different degrees of light and shade. While form drawing suggests relief, value drawing represents it, and it also represents by translating them into their corresponding tones of gray, the values of color. In form drawing, a draftsman representing a red object and a yellow one, would be satisfied to give correct proportions and outlines with one or two principal shadows, while a value drawing of the same objects would show not only the relation of the shadows as they are in nature, but also the further truth that the red object was as a whole darker than the yellow one. The light side of the red object might even be found to be darker in **value** or tone than the shadow side of the yellow form.

29. **Values.** Drawing has been called the science of art, but artists have rarely approved the introduction of scientific methods in the study of drawing, fearing lest the use of formulas should lead to dull mechanical results. Students are left to discover methods and formulas of their own. It is true that every successful draftsman or artist has a method which he has worked out for himself, but he usually feels it to be so much a matter of his own individuality, that he is reluctant to impose it on students, who are likely to confound what is a vital principle with a personal mannerism, and by imitation of the latter injure the quality of personal expression which is so important in all creative work. So there is an inclination among drawing teachers to distrust anything which tends even to formulate the principles of drawing. Recently there has been, however, a distinct advance in the study of these principles, under the leadership of Dr. Denman W. Ross, of Harvard University, who has made it possible for the first time to speak with exactness of colors and values. As Dr. Ross has permitted the use of his valuable scale in this text book, it will greatly assist in making tangible and clear, what would otherwise be obscure and difficult to explain.

The word **values** as used in the text book refers entirely to relations of light and dark. For instance, the value of a given color, is represented by a tone of gray which has the same density or degree of light and dark that the color has. The value of a spot of red paint on a white ground is expressed by a spot of gray paint which appears as dark on the white ground as does the red paint, but from which the color principle has been omitted. A good photograph of a colored picture gives the values of the picture. A poor photograph, on the contrary, distorts the values and blues are often found too light, while reds and yellows will be too dark to truthfully express the values of the original color.

30. **The Value Scale.** All possible values which can be represented in drawing, lie between the pure whites of paper or pig-

ments and the pure black of pencil, ink, or other pigments. In order to think or speak precisely of the great range of values between black and white, it is necessary that they shall be classified in some way. It is not sufficient to say that a given shadow is light, or medium, or dark in value. Dr. Ross has overcome the difficulty by arranging a value scale of nine equal intervals, which covers the whole range from pure white to pure black. Each interval has its appropriate designation and a convenient abbreviation. This scale affords a practical working basis for the study of values. It is evident that while the individual scale does not include all possible values, it can readily be enlarged indefinitely by introducing values between those of the scale as described. As a matter of fact, any differences in value that might come between any two intervals of the scale would rarely be represented, as it is the practice in drawing to simplify values as much as possible; that is to consider the general value of a mass, rather than to cut it up into a number of slightly varying tones which are not necessary for expressing anything of importance in the object.

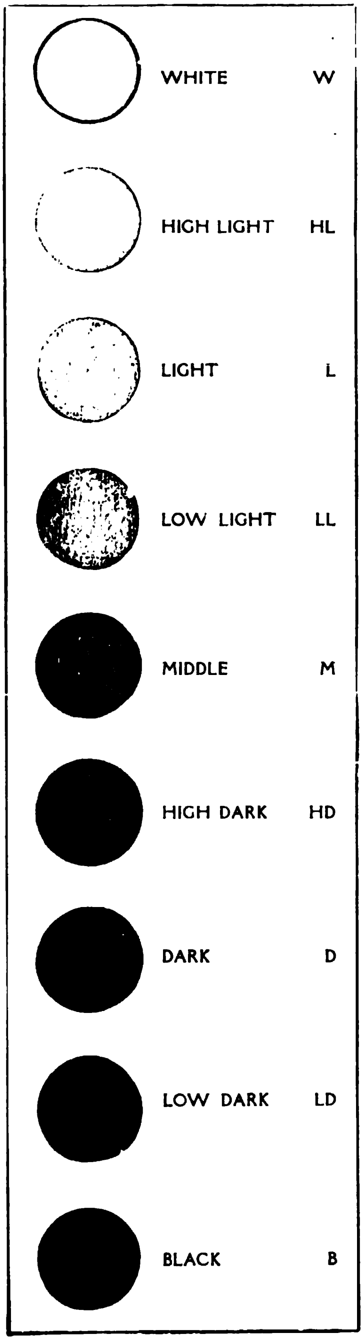

Fig. 24. Value Scale.

31. How to Make a Value Scale. Fig. 24 shows a value scale with the names of the intervals and their abbreviations. In making a value scale the student should work in pencil, confining each interval within a circle three-quarters of an inch in diameter. White will be represented by the white paper with a circle penciled about it. Black (B) and white (W) should be established first, then the middle value (M), light (L) and dark (D); afterward the remaining values, low light (LL), high light (HL), low dark (LD) and high dark (HD).

32. How to Use a Value Scale. When the objects to be drawn are neutral in color, that is, are black, white, or gray, the relative values are perceived without special difficulty. When the objects are in color, the draftsman is obliged to translate the color element into terms of light and dark.

In order to determine the value of any surface, it is a help to compare the surface with a piece of white paper held in such a way that it receives the greatest amount of light. It not infrequently happens that two surfaces quite different in color will be of exactly the same value. The student should make a practice of observing the relative values of things about him, even when he is not engaged in drawing.

Place a sheet of white paper in the sunlight as it falls through a window and compare its value with that of white paper further in the room and outside of the sunlight. Try a similar experiment with black. These merely show what everyone may suppose that he knows already—that the less light a surface receives the darker value it appears to have. As a matter of fact, beginners are more ready to accept this truth with regard to color than they are when it relates to black and white.

An instructive way of studying values is to look through a closed window and compare the values of forms outside to the value of the window sash. Even when the sash is painted white, it will often be observed to appear darker than any shadow out of doors.

33. General Directions for Drawing the Examination Plates. The examination plates are planned to give as great a variety to the style of drawing as possible. The architect is called upon to use freehand drawing in two general ways; to make working drawings of ornament, either painted or carved, and to make, for reference, sketches or notes, more or less elaborate, from ornament already in existence, or from buildings either entire or in part, as well as from their landscape setting. This course will not include drawing of architecture and landscape.

In making a working drawing of ornament every shape and curve should be drawn to perfection, with clean, careful lines, in order that there shall be no opportunity for the craftsman who executes the work to interpret it differently from the designer's intention. Light and shade are used sparingly as the exact amount of relief is indicated by sections.

In making sketches or notes, while proportions must be accurately studied, form may be suggested by a much freer quality of line. In a working drawing light and shade may be merely indicated or may be carried to any degree of elaboration. The natural way of teaching this kind of drawing is to work from the objects themselves or from casts. This is not possible in a correspondence course, but all the principles of sketching may be very well taught by drawing from photographs of ornament, and this method has some decided advantages of its own for a beginner. The light and shade in the photograph are fixed, while in sketching objects out of doors it changes constantly, and even indoors is subject to some fluctuation; and then, in the photograph the object is more isolated from its surroundings and so is less confusing to perceive.

In order to train the sense of proportion as thoroughly as possible, the plates are to be executed on a much larger scale than the examples, but at no fixed scale. Plan each drawing to be as large as possible, where no dimensions are given, but do not allow any point in the drawing to approach nearer than one inch to the border line.

34. **Varieties of Shading.** In drawing in pen and ink, all effects of shadow are made by lines, and different values are obtained by varying the width of lines, or of the spaces between the lines, or by both. In any case the integrity of each line must be preserved and there can be very little crossing or touching of shade lines, as that causes a black spot in the tone unless lines cross each other systematically and produce **cross hatching.** With the pencil, however, owing to its granular character one may produce a tone without any lines; a tone made up of lines which by touching or overlapping produce a soft, blended effect, in which the general

direction of the strokes is still visible, or a tone made up of pure lines as in pen work. In general it does not matter so much, as in pen drawing, if lines touch or overlap. Indeed, the natural character of the pencil line leads to a treatment which includes both pure lines and more or less blended effects.

35. **Directions of Shade Lines.** It is always a very important matter to decide what direction shade lines shall take. While it is impossible to give rules for it, a good general principle is to make the direction of the lines follow the contours of the form. The easiest and simplest method is to make all the lines upright. This method is a very popular one with architects. The objections to it are monotony and a lack of expression, but it is certainly a very safe method and far preferable to one where desire for variety has been carried too far and lines lead the eye in a great number of different directions which contradict the general lines of the surface or form. A natural treatment is to adapt the direction of lines to the character of the surface represented; that is, to treat curved surfaces with curving lines and flat planes with straight lines, and in general, lines may very well follow either the contours or the surfaces of the form. In that way variety is obtained and the direction of the shading helps to express the character of the thing represented. This principle must, however, be modified when it leads to the introduction of violently opposing sets of lines. Abrupt transitions must be avoided and the change from one direction to another must be accomplished gradually.

Where a large surface is to receive a tone, the tone can best be made by a series of rather short lines side by side with succeeding series juxtaposed. The lengths of the lines in each of the series must vary considerably in order that the breaks in the lines may not occur in even rows, producing lines of white through the tone. (See Fig. 25.)

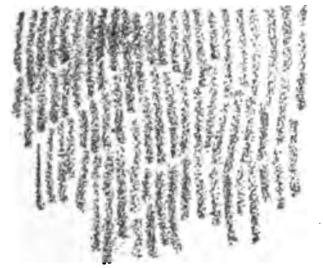
Fig. 25. Method of Breaking Lines Covering a Large Surface.

The crossing of one system of parallel lines by another system is called **cross hatching.** This method probably originated in copperplate engraving, to which it is very well adapted, especially as a means of modifying and deepening tones. It also changes and breaks up the rather stringy texture produced by a succession of long parallel lines. It has now become somewhat obsolete as a general method for pen or pencil drawing, largely because the result looks labored, for it is always desirable to produce effects more simply and directly, that is, with one set of lines instead of two or more. If the tone made by one set of lines needs darkening, it is now more usual to go over the first tone with another set of lines in the same direction.

A great many drawings have been made with shade lines all in a diagonal direction, but this is open to serious objection and should be avoided. A diagonal line is always opposed to the principle of gravitation, and tends to render objects unstable and give them the appearance of tilting. It is often desirable to begin a tone with diagonal lines which, however, should gradually be made to swing into either an upright or horizontal direction.

EXAMINATION PAPER

FREEHAND DRAWING.

Materials Required. One Wolff's solid ink black pencil; one F pencil; one HB pencil; two dozen sheets of paper (same as practice paper of other courses, but to be used for examination sheets in this); one red soft rubber; one medium rubber—green or red, with wedge ends; one drawing board; six thumb tacks; one box natural drawing models; one Cross slate; one Cross pencil; one-half dozen sheets of tracing paper.

After the preliminary practice with straight lines and curves the student may proceed to execute Plates I and II.

PLATE I.

The principal dimensions in inches are indicated on the model plate. All dimensions and proportions should however be determined by the eye alone. Measurements may be used as a test after the squares are laid in. The figures on the left should be executed first, in order to avoid rubbing by the hand and sleeve.

Figs. 1, 2, 3, 4, 5 are motives from Egyptian painted decoration. Figs. 1, 2, 4 and 5 are all derived from or suggested by patterns produced by plaiting or wearing. The borders of Fig. 3 are derived from bundles of reeds bound together.

As all the figures are large and simple, they should be executed with a rather wide line drawn with the F pencil. Draw the construction lines on this and on all other plates where they are necessary, so lightly that they can be perfectly erased without leaving any indentation in the paper. After the construction lines are drawn out in Figs. 4 and 5, strengthen the lines of the pattern. In erasing, much of the pattern will be removed. This time go over each line with a single stroke of the solid ink pencil. Do not turn the paper in drawing diagonal and vertical lines. They are given especially to train the hand to execute such lines. By turning the paper the exercise becomes one of drawing horizontal lines, which are the least difficult.

Fig. 6 is the skeleton of a very common type of ornament consisting of curved lines radiating from a point at the base, on either side of a central axis.

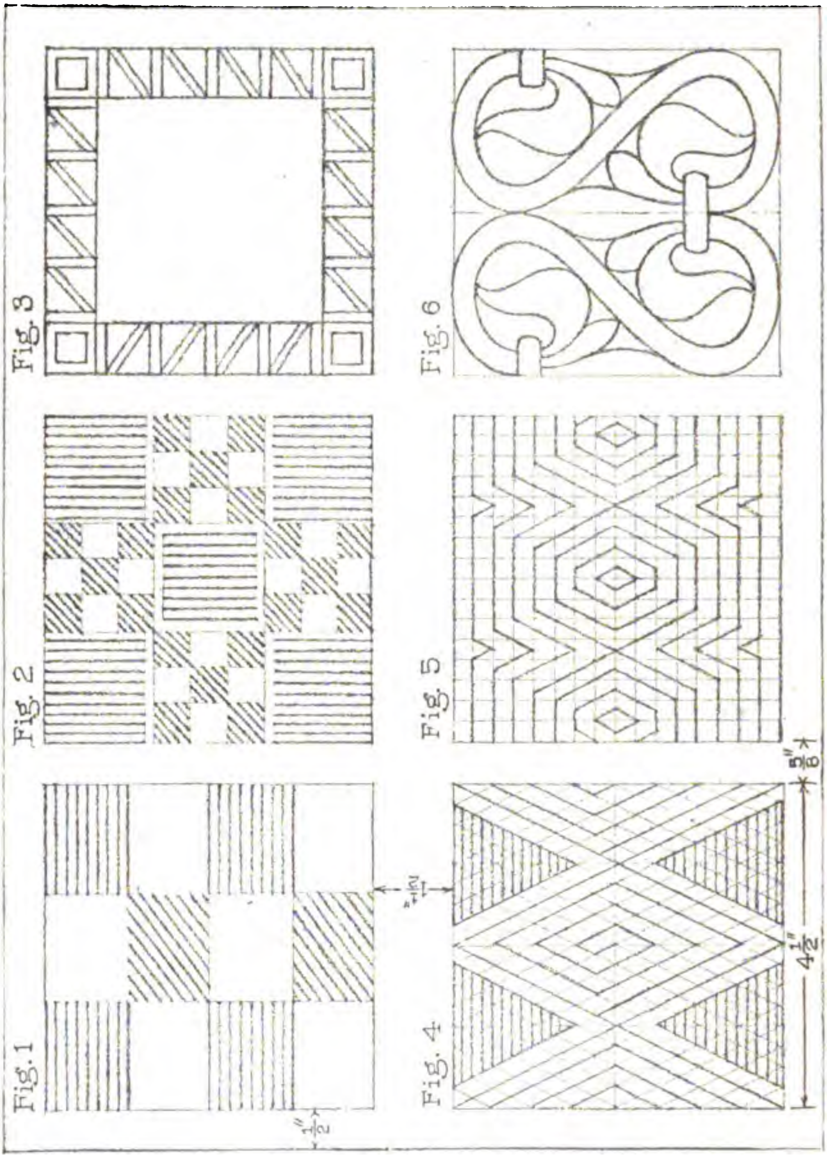

PLATE I.
Motives of Common Types of Ornament.

PLATE II.

Fig. 1 is the basis of a large class of ornament founded on the lines of organic growth, called scrolls or meanders.

Fig. 2 is an Egyptian border consisting of alternate flower and bud forms of the lotus, the most typical and universal of all the Egyptian decorative units. The outline of the flower displays the Egyptian feeling for subtlety and refinement of curve. Observe how the short rounded curve of the base passes into a long subtle curve which becomes almost straight and terminates in a short full turn at the end.

Fig. 3 is a simple form of the guilloche (pronounced gheeyoche), a motive which first becomes common in Assyrian decoration and is afterward incorporated into all the succeeding styles.

Fig. 4 is the skeleton of a border motive where the units are disposed on either side of the long axis of the border.

Figs. 5 and 7 are varieties of the Greek anthemeum or honeysuckle pattern, one of the most subtle and perfect of all ornamental forms. Observe in Fig. 5 the quality of the curves—the contrast of full rounded parts with long curves almost straight which characterize the Egyptian lotus. Note in both examples that there is a regular ratio of increase both in the size of the lobes and in the spaces between each, from the lowest one up to the center. It is invariably the rule that each lobe shall be continued to the base without touching its neighbor.

Fig. 6 is an Egyptian "all-over" or repeating pattern painted on wall surfaces. It is made up of continuous circles filled with lotus forms and the intervening spaces with buds.

PLATE III.

This plate is to contain nine outline drawings illustrating Rules 8, 12, 13, 14, 15, 17, 18, 19, 20. The drawings may be made and corrected on the slate and then copied on to the paper or they may be drawn directly on the paper. They may be from the models or from simple geometric objects such as boxes, blocks, cups, pans, plates, spools, flower pots, bottles, etc.

PLATE IV.*

These are characteristic forms of Greek vases. Fig. 1, the Lechy-

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* NOTE. This plate and all succeeding ones are to be surrounded by a border line, drawn freehand one inch from the edge of the paper.

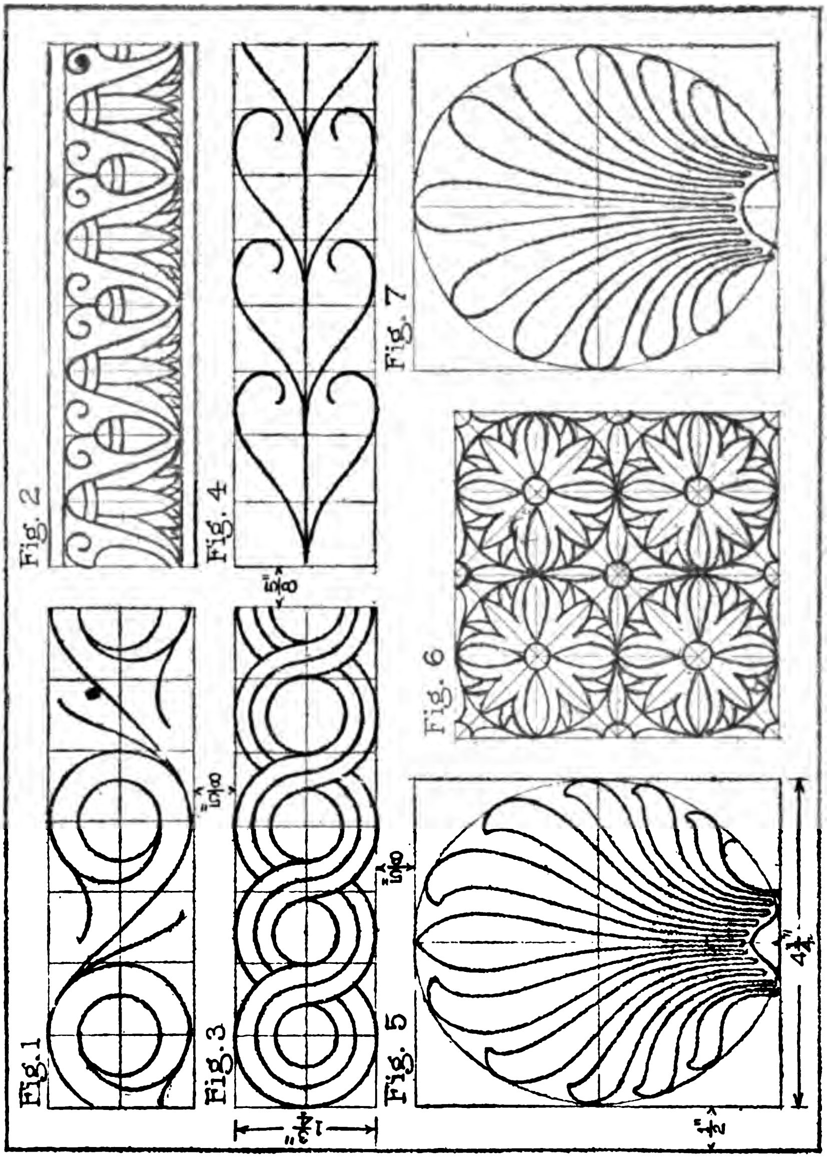


PLATE II.
Typical Egyptian, Assyrian and Greek Motives.

thos, was used to hold oil, Fig. 2, the Kantheros, is one form of the drinking cup, and Fig. 3, the Hydria, for pouring water.

The drawing of these vases includes a great variety of beautiful curves. They are to be executed entirely in outline, and both contours and bands of ornament and the relative sizes of each are to be preserved.

Calculate the heights so that the bases shall each be one inch from above the border line and the upper point of Fig. 3 about one inch below the border line. In sketching them in, first place a construction line to represent the central axis. Across this, sketch the outlines of the horizontal bands and then sketch the contours, following the general directions given in Sections 21 and 25. Remember that lines are to be drawn lightly and corrections made by new lines and not by erasures. Use the arm movement as much as possible in drawing the curves. Before executing the examination paper, practice drawing each vase entirely without corrections of the lines.

PLATE V.

Fig. 1 is from the pavement in the Baptistery at Florence and is in the style called Tuscan Romanesque. The pointed acanthus leaves in the small border at the top, are identical in character with the Byzantine acanthus.

This drawing is to be treated like a sketch made from the object. After sketching in the pattern and correcting in the usual way by drawing new lines, erase superfluous lines and strengthen the outlines by lines made with one stroke. The final outline should, however, be loose and free in character and express the somewhat roughened edges of the pattern in white. This does not mean that the direction of the line must vary enough to distort any shapes. Observe that most of the shapes appear to be perfectly symmetrical only their edges seem slightly softened and broken. Fill in the background with a tone equal to the dark (D) of the value scale. Make this tone by upright lines nearly touching each other and if the value is too light at first, go over them again by lines in the same direction. If a background line occasionally runs over the outline, it will help to produce the effect of the original.

Figs. 2, 3, 4 and 5 comprise typical forms of Greek decorated mouldings. The examples have much the character of a working

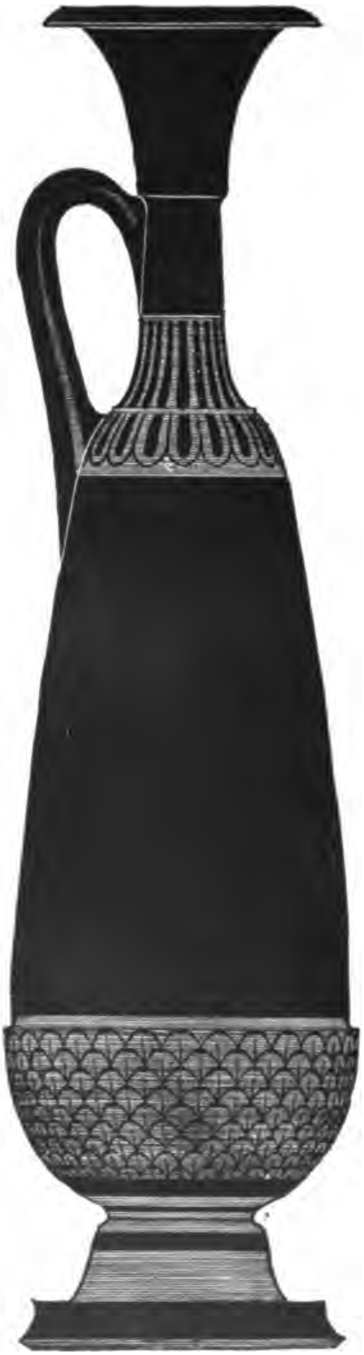


PLATE IV. FIG. 1.
The Lechythos.
Typical Greek Vase Used to Hold Oil.

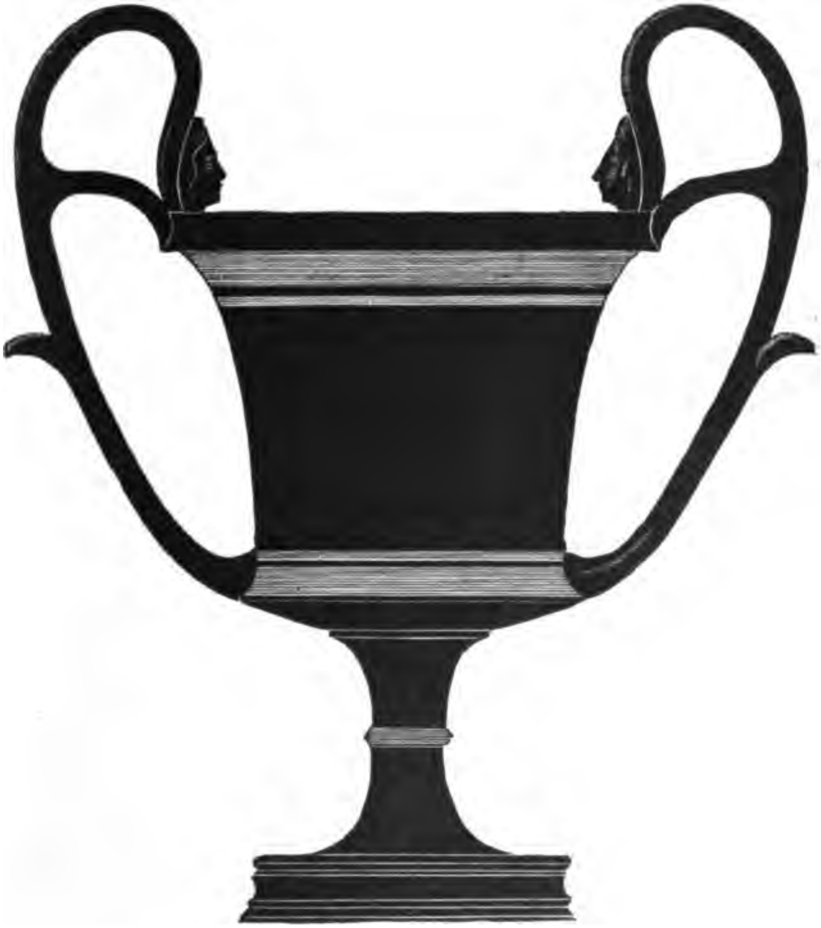


PLATE IV. FIG. 2.

The Kantheros.

Typical Greek Vase Used for a Drinking Cup.

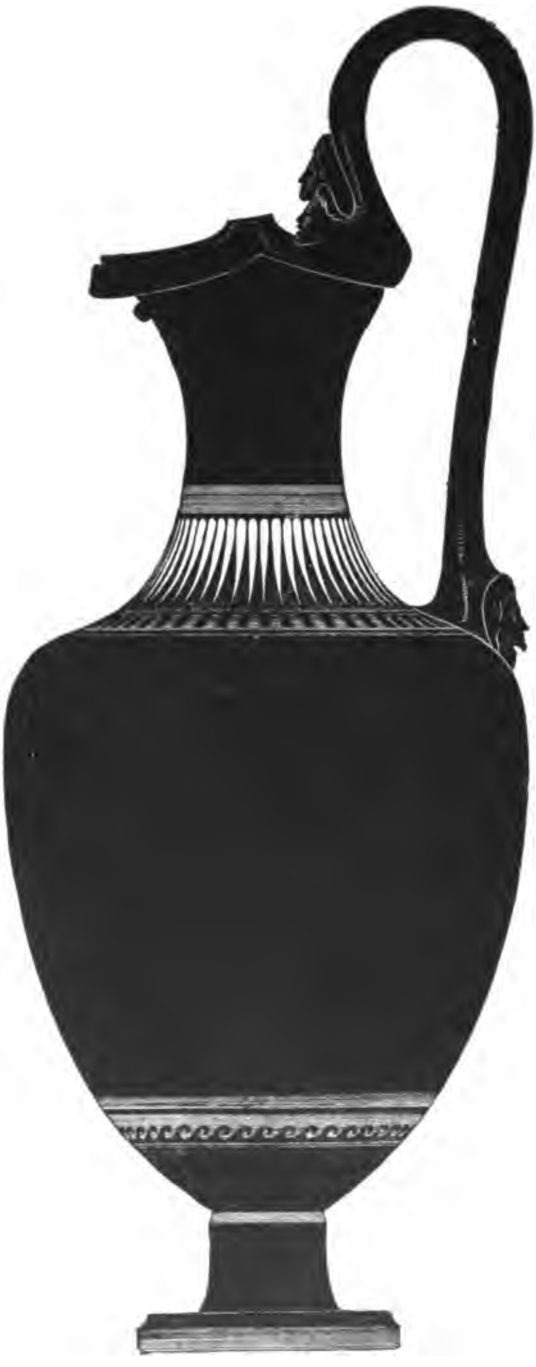


PLATE IV. FIG. 3.

The Hydria.

Typical Greek Vase Used for Pouring Water.

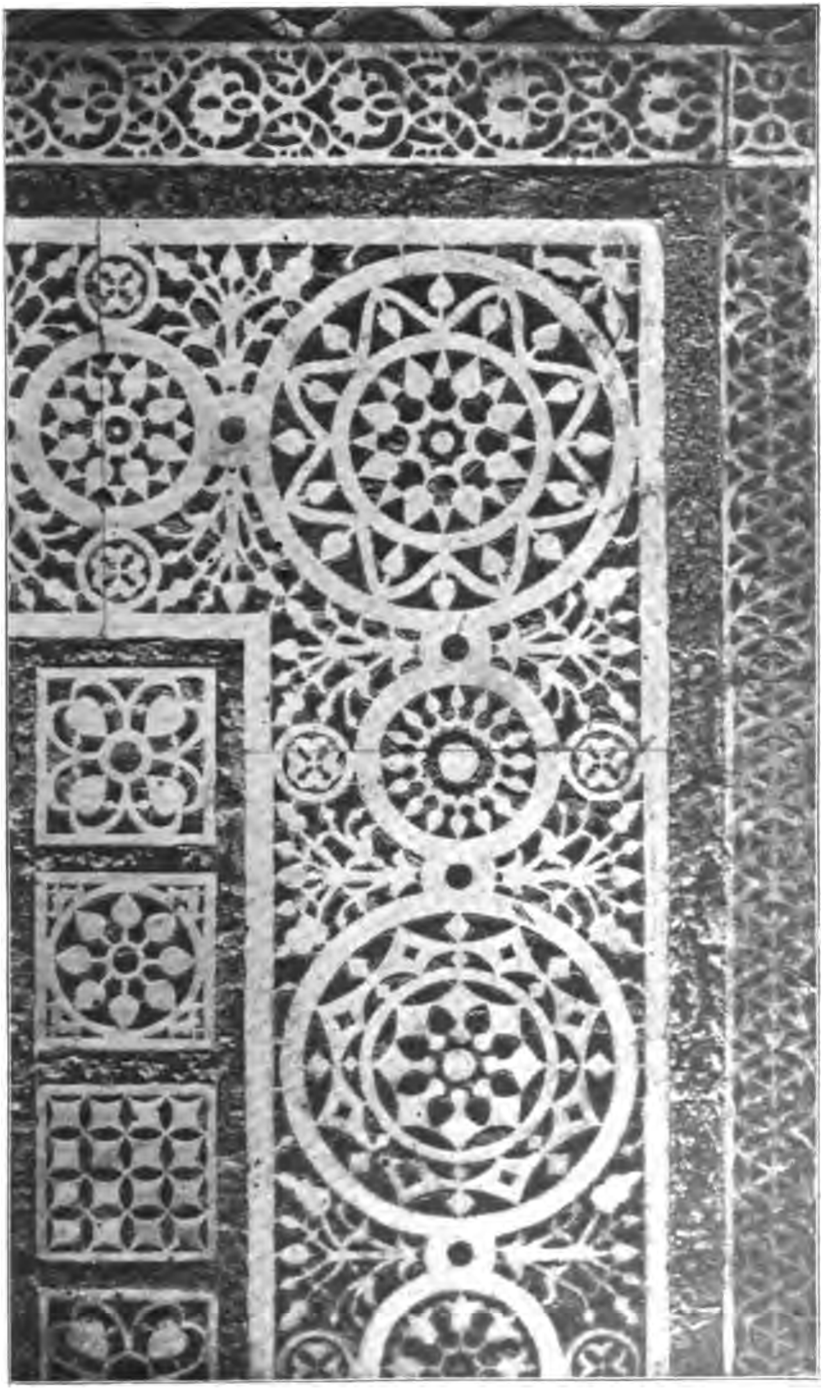
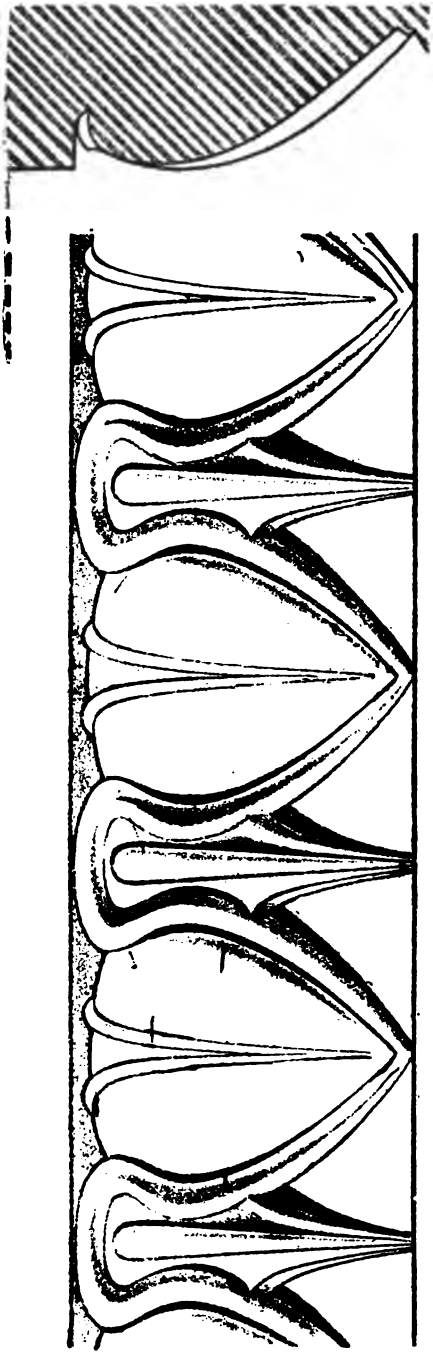


PLATE V. FIG. 1.
Pavement from the Baptistery, Florence.



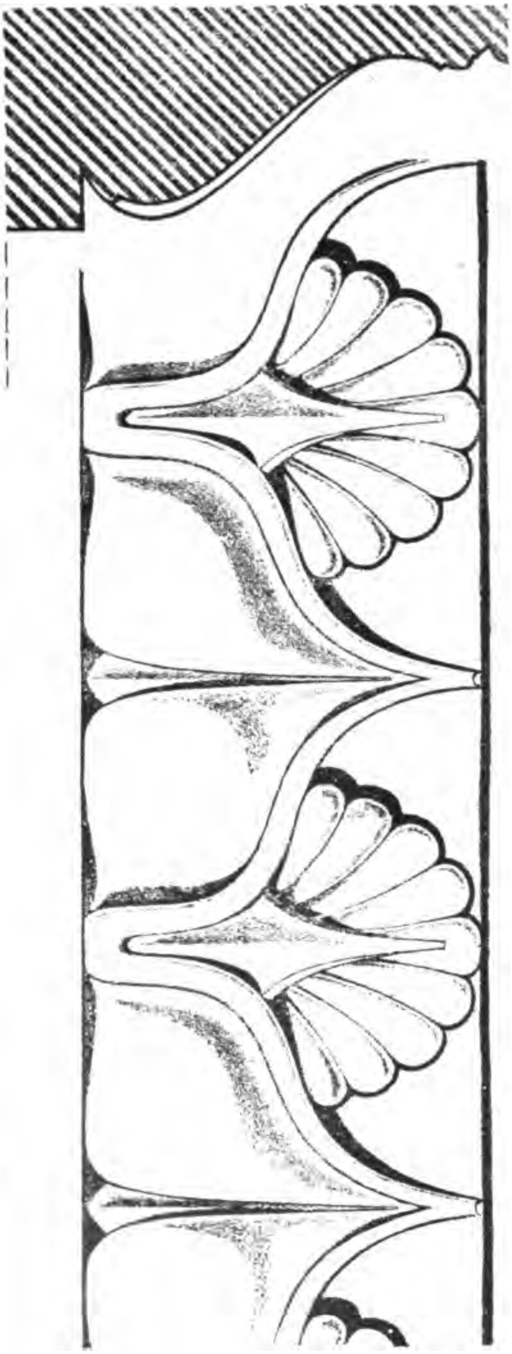


FIG. 2. PLATE V. FIG. 3.

Typical Forms of Greek Decorated Mouldings.

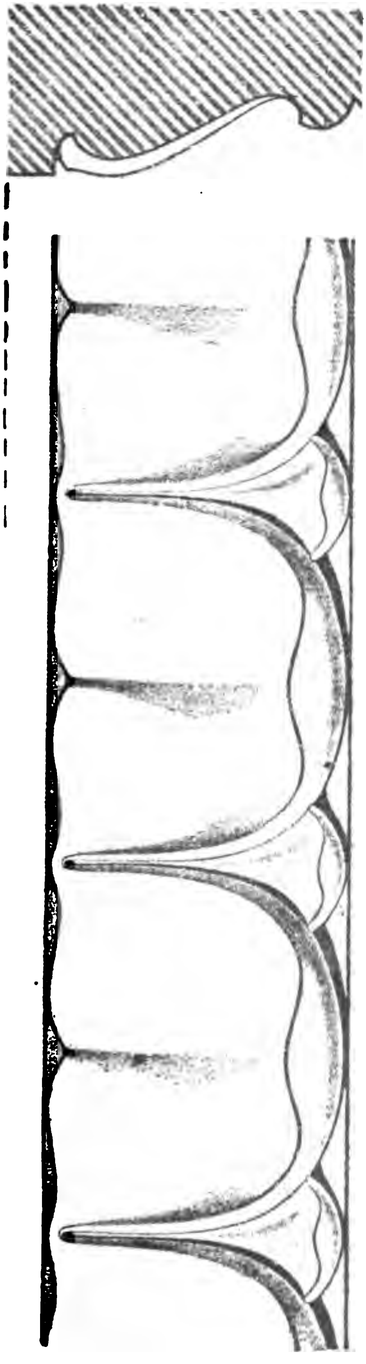


FIG. 4.

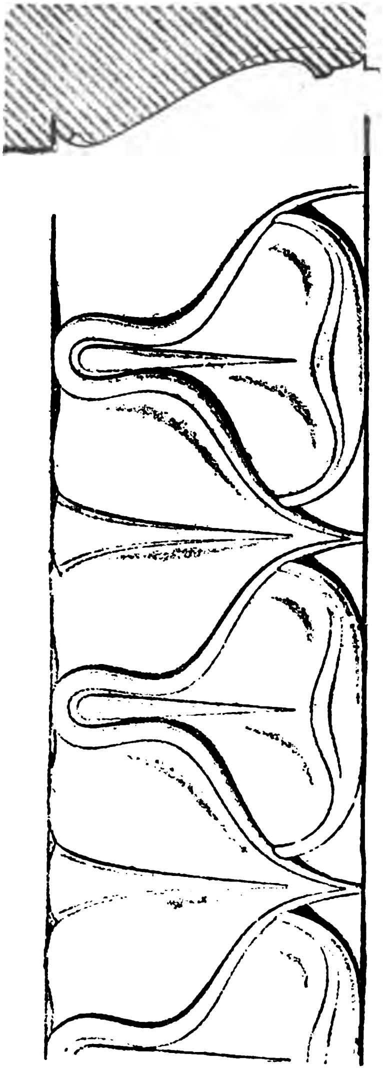


FIG. 5.

PLATE V.

Typical Forms of Greek Decorated Mouldings.

drawing and the plates are to be enlarged copies, but instead of following the character of the light and shade of the original, the shadows are to be executed by upright lines. (See Section 37.) The darker shadows are to be the value of dark (D) of the scale, the lighter ones the value of middle (M).

PLATE VI.

Place these drawings so that there will be at least an inch between them and about half an inch between the border line and the top and bottom.

Fig. 1 is from a drawing of a wrought iron grille in a church in Prague. Some idea of the shape of the pieces of iron is conveyed by the occasional lines of shading. The pattern will be seen to be disposed on radii dividing the circle into sixths. Construct the skeleton of the pattern shown, establishing first an equilateral triangle and the lines which subdivide its angles and sides. About this draw the inner line of the circle and extend the lines which subdivide the angles of the triangles, to form the six radii of the circle. Complete the outlines of the pattern before drawing the shading lines. This drawing with its lines and curves all carefully perfected represents the kind of working drawing which an architect might give to an ironsmith to work with, although in a working drawing, a section of the iron would be given and each motive of the design would propably be drawn out only once and then as it was repeated it would be merely indicated by a line or two sketched in.

Fig. 2 is from a photograph of a wrought iron grille at Lucca in the style of the Italian Renaissance. The drawing to be made from this, the student must consider to be a sketch, the sort of note or memorandum he might make were he before the original.

The accompanying detail gives a suggestion of the proper treatment. The general shape of the whole outline should be indicated and the larger geometric subdivisions; the details of two of the compartments suggested by light lines and those of the remainder either omitted or very slightly suggested. Try to make the drawing suggest the "hammered" quality of the iron. Although the curves are all beautifully felt, there are slight variations in them produced by the hammer, or they are bent out of shape by time, and the thickness of the iron varies sometimes by intention and sometimes by acci-

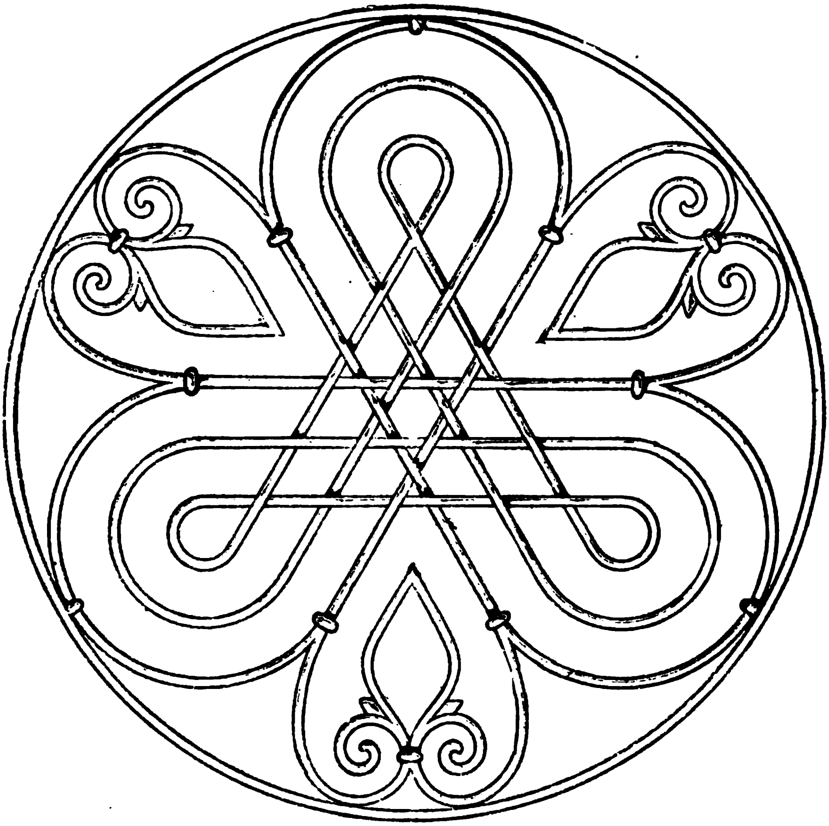


PLATE VI. FIG. 1.
Wrought Iron Grille, Prague

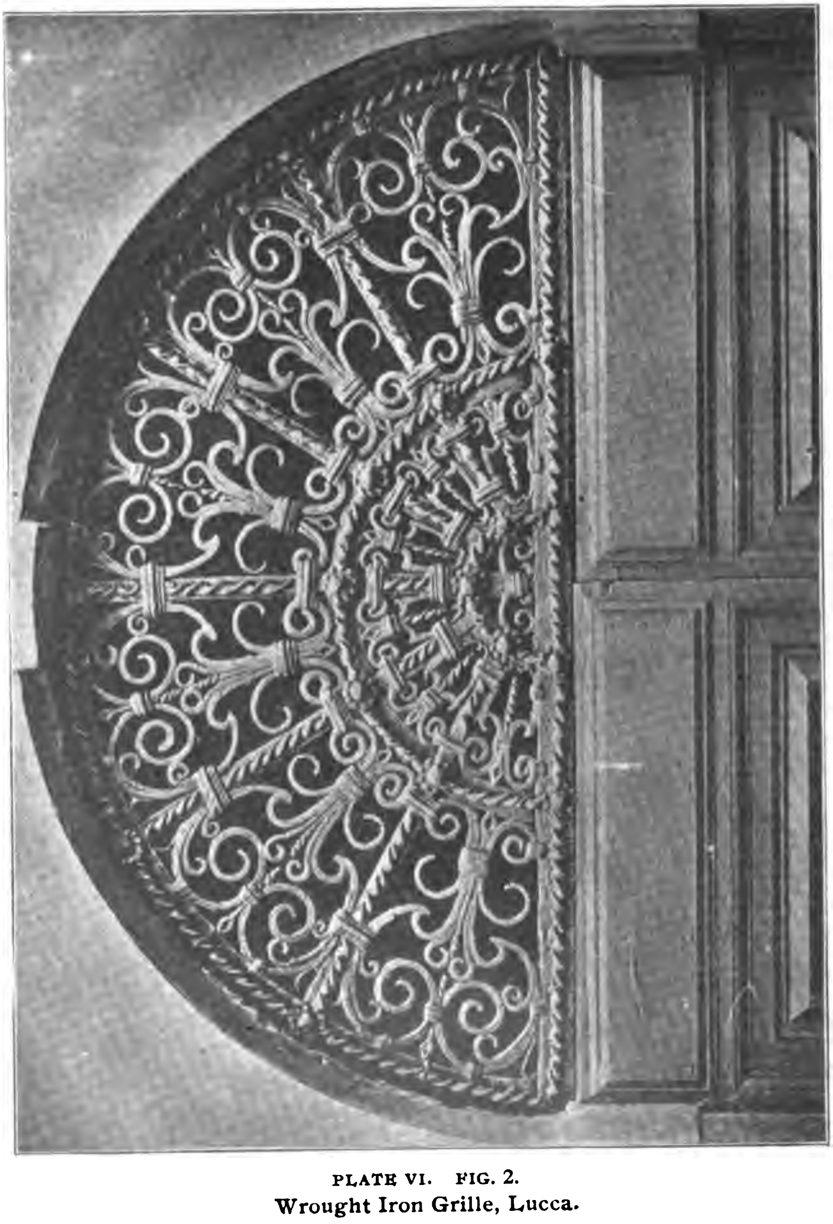
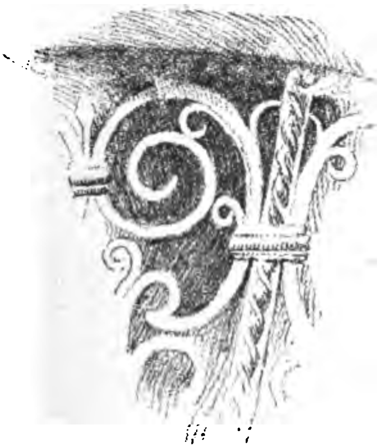


PLATE VI. FIG. 2.
Wrought Iron Grille, Lucca.

dent. Take care, however, not to exaggerate the freedom of the lines and do not carry the variation so far that curves are distorted. Make the drawing in outline first with a line which breaks occasionally, with portions of the line omitted. This helps to indicate the texture of the iron and suggests its free hand-made character.



Detail of Plate VI, Fig. 2.

That part of the background which in the photograph appears black behind the iron, should be filled in with a tone equal to the dark (D) of the value scale. It should only be placed behind the two compartments which are most carefully drawn, with perhaps an irregular patch of it in the adjoining compartment. In making the background use single pencil strokes, side by side, with the solid ink pencil, very near together or occasionally touching. Give a slight curve to each stroke. The direction of the lines may be either upright, or they may keep the leading direction of the general lines of the pattern, but they should not be stiff or mechanical. If the value is not dark enough another set of lines may be made over the first ones, keeping the same direction. The only parts of the ironwork itself which require shading are those twisted pieces which mark the subdivision, the outer edge, and the clasp. For this use a tone equal to the middle (M) of the value scale. Avoid explaining too carefully the twists and use the shading only in the dark side. Use a few broken outlines on the right side, just enough to suggest it and do not darken the flat piece of iron behind the twists except on the shadow side. Do not count the number of twists but indicate them in their proper size and the effect will be near enough for this kind of a drawing. Shade only those twists which are nearest the compartments which are detailed; from them let the detail gradually die away.

PLATE VII.

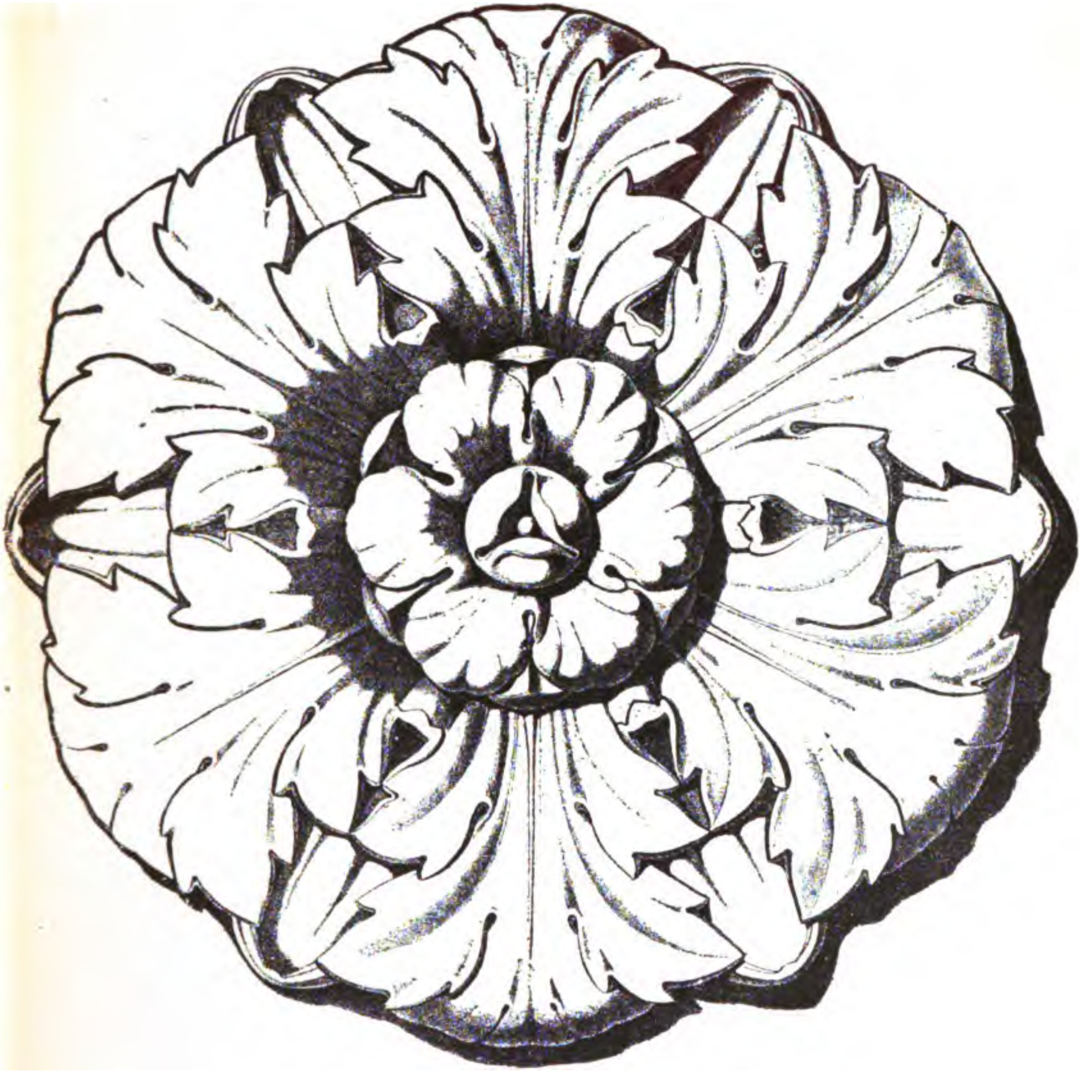
This figure is a rosette made up of the Roman or soft acanthus, and the drawing has the general character of a working drawing. Every part is very clearly expressed in outline, slightly shadowed, and a section explains the exact contours. In drawing the outline of the leaflets, observe that one edge, usually the upper is generally expressed by a simple curve and the other edge by a compound curve, the variation in which, however, is slight. Draw a circle first to contain the outer edge of the rosette and sketch in lightly the main rib or central axis of each leaf. Then block in the general form of the leaves, not showing the subdivisions at edges. Next place the *eyes*—the small elliptical spots which separate one lobe from another—and draw the main ribs of each lobe, finally detailing the leaflets in each lobe. In shading use the value dark (D) for the darkest values and the middle value (M) for the others, and instead of producing a perfectly blended tone as in the original, let the tone retain some suggestion of lines, the general direction of which should follow that of the main ribs in the leaves. In the shadow of the rosette on the background, let the lines be upright. Lines naturally show less in very dark values than in lighter tones, for it is difficult to produce the darker values without going over the lines with another set and that has a tendency to blend all the lines into a general tone.

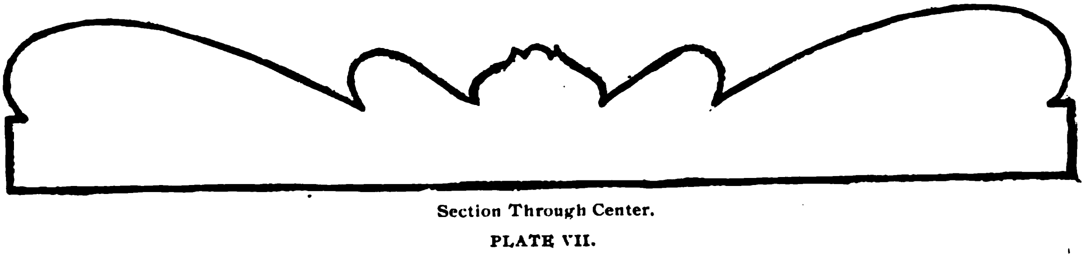
PLATE VIII.

Plate VIII is a sculptured frieze ornament introducing various forms of the Roman or soft acanthus. In this as in all scroll drawing, the skeleton of the pattern should be carefully drawn, then the leaves and rosettes disposed upon it. Always draw the big general form of the acanthus, and proceed gradually to the details as described in the directions for Plate VII. This like Plate VII, has the general character of a working drawing, only in this case there is no section. Use the same values and same suggestions for directions of line as in Plate VII.

PLATE IX.

This plate is an example of the Byzantine acanthus on a fragment in the Capitoline Museum. In drawing this, place the central axis or main rib of the leaf first, then establish the position of the eyes—the egg-shaped cuts which separate the lobes. The general contour of the lobes and their main ribs should next be blocked in before the final disposition of the points or leaflets is determined.





Section Through Center.

PLATE VII.

Acanthus Rosette.

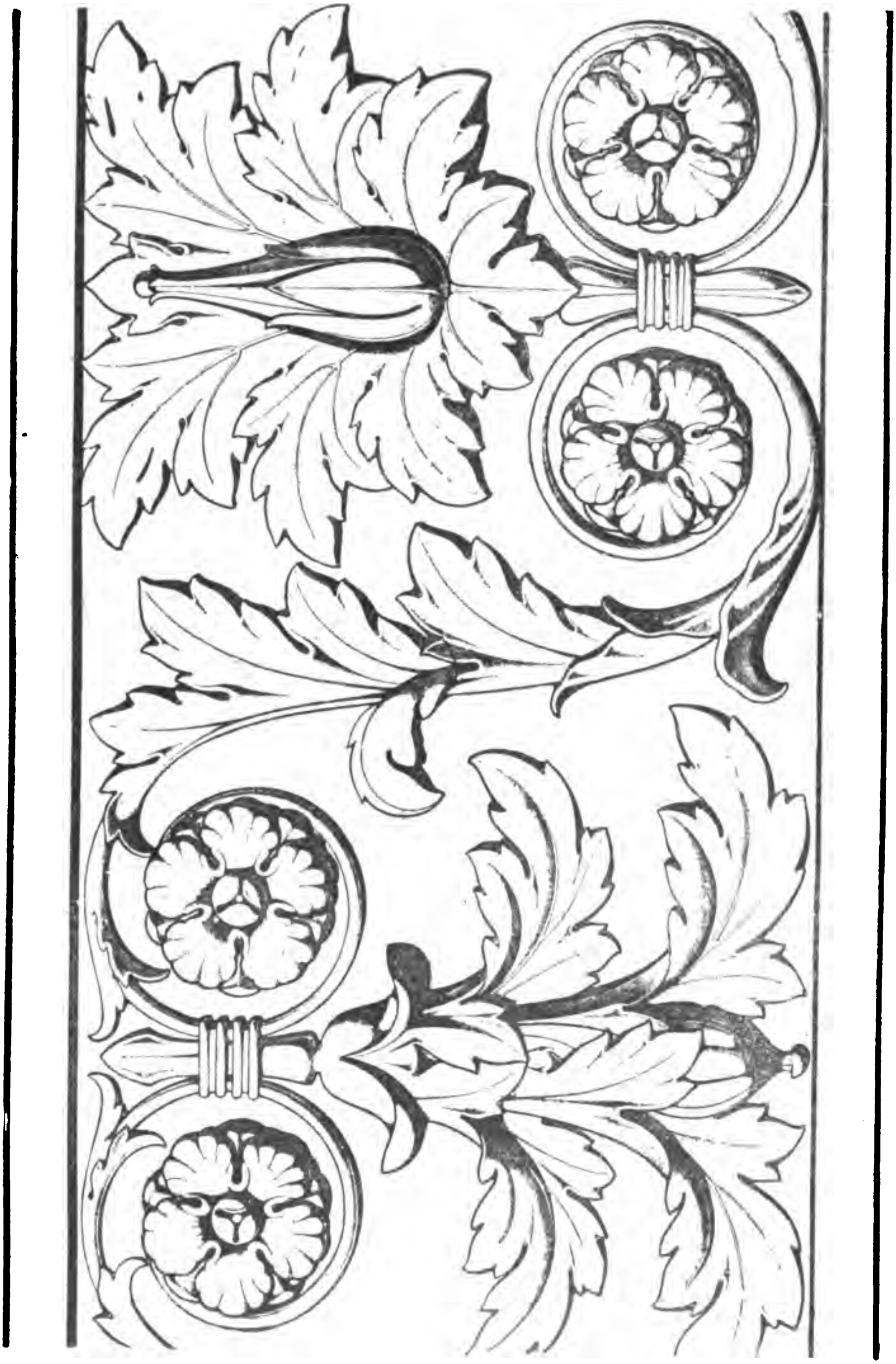


PLATE VIII.

Acanthus Frieze.

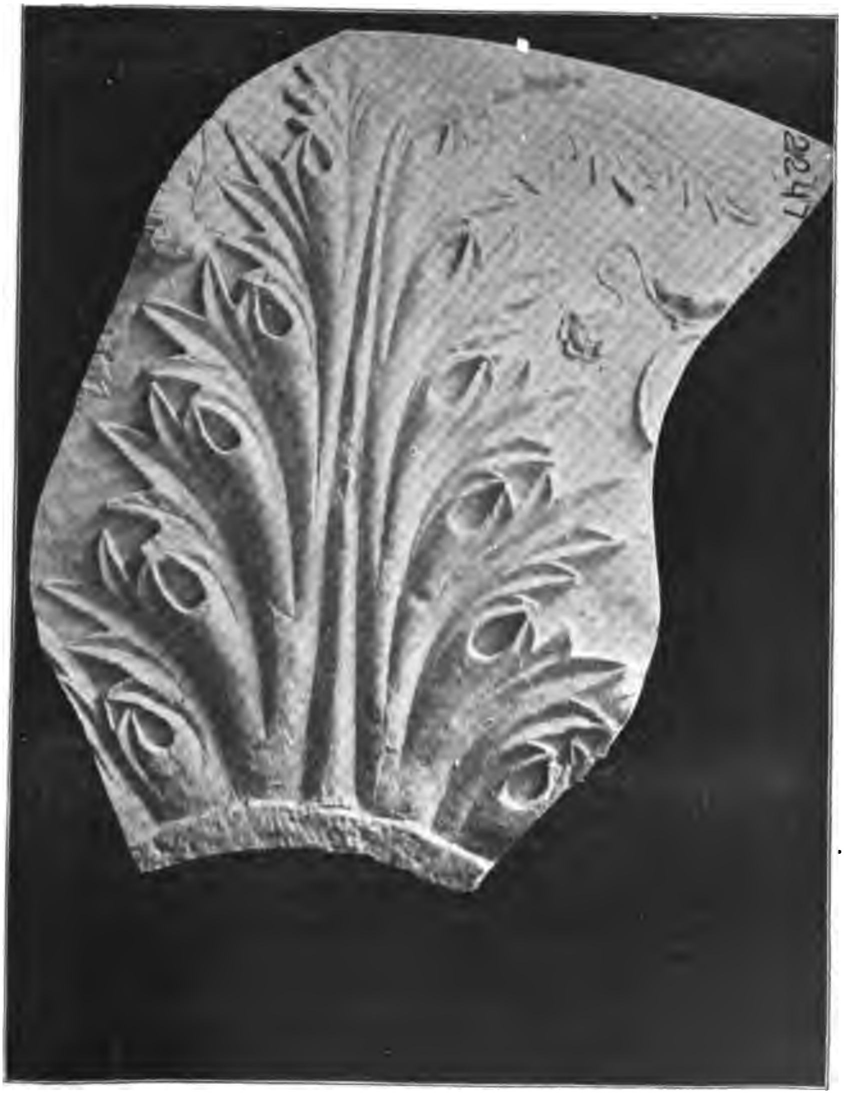


PLATE IX.
This is also to be drawn as Fig. 1, Plate X.
Byzantine Acanthus, from a fragment in the Capitoline Museum.

The drawing of this plate is to be enlarged to about ten inches in height and well placed on the sheet with the center of the drawing coinciding with the center of the plate. This drawing is to be made by the use of two values only, with white, and the student may select his own values. The object is to select the most important features and to omit as much as possible. It would be well for the student to first try to see how much he can express with one value and white. The values are to be obtained by upright lines. Outlines are to be omitted as far as possible in the finished sketch and forms are to be expressed by the shapes of the masses of shadow. Where only two values and white are to be used, it is desirable to leave as much white as possible and not allow the shadow values to run too near to black as that produces too harsh a contrast with the white. On the other hand, if the shadow values are too high in the scale, that is too near white, the drawing becomes weak and washed out in effect. As this drawing is to be large in scale, it should be made with the solid ink pencil and with wide pencil strokes. After the outline has been sketched in, the shading or "rendering" may be studied, first on tracing paper over the drawing. There should be no attempt at rendering the background in this drawing.

PLATE X.

Figs. 1 and 2 are to be placed on this plate, but Fig. 1 is to be rendered this time as near to the **true values** as it is possibie to go by using four values and white in shading. The pencil lines should be blended together somewhat, but the general direction of the shading should follow the central axis of the lobes. Only the leaf itself is to be drawn and the background value should be allowed to break in an irregular line about the leaf. It should not be carried out to an edge which would represent the shape of the entire fragment of stone on which the leaf is carved. In studying the shapes of the different shadows it is well at first to exaggerate somewhat and give each value a clean, definite shape even if the edges appear somewhat indefinite in the original. At the last those edges which are blurred may be blended together.

Fig. 2 is a Byzantine capital from the church of San Vitale, at Ravenna. This is to be drawn so that the lines of the column shall fade off gradually into nothing and end in a broken edge instead of stopping on a horizontal line as in the original. The top of the drawing above the great cushion which rests on the capital proper should also fade off into nothing and with a broken line instead of the horizontal straight line. A small broken area of the background value should be placed either side of the capital. In drawing an object like this which is full of small detail there is danger of losing the larger qualities of solidity and roundness by insisting too much upon the small parts and there is also danger of making the drawing too spotty. It is a good principle to decide at first that the detail is to be expressed either in the shadow or in the light, but not equally in both. This principle is based on one of the facts of vision, for in looking at an object one sees only a comparatively small amount of detail; what falls on either side of the spot on which the eye is focused appears blurred and indistinct. In an object of this kind whose section is circular, one can best express the shape by concentrating the study of detail at the point where the light leaves off and shadow begins, representing less and less detail as the object turns away from the spectator. In this drawing, however, there may be more detail expressed in the shadow than in the light, but remember that outlines of objects in shadow lose their sharpness and become softened. Do not attempt to show all the grooves in the parts in shadow; indicate one or two principal ones and indicate more and more detail as the leaves approach the point where the light begins. There the richness of detail may be fully represented, but as the forms pass into the light, omit more and more detail. Again observe that any small plane of shadow surrounded by intense light, if examined in detail, appears darker by contrast, but if represented as dark as it appears it becomes **spotty** and **out of value.** If observed in relation to the whole object its real value will be seen to be lighter than it appears when examined by itself. Use white and four values to be determined by the student. Guard against too strong contrasts of values within the shadow as it cuts it up and destroys its unity, and in every drawing made, show clearly just which is the shadow side and which is the light. That is, do not place so many shadow values within the light that it destroys it, and do not invade shadows with too many lights and reflected lights. Note that it is characteristic of the Byzantine acanthus to have the points of every tine or lobe touch something; no points are left free, but observe also that the points have some substance and width at the place they touch and must not be represented by a mere thread of light. It would be a mistake to introduce much variety of direction in the lines in this drawing, especially in the shadows, as it would "break it up" too much. The concave line of the contour of the capital may well determine the dominant direction of the lines which should not be very distinct as lines, but should blend considerably into general tones. Wherever a plane of shadow stops with a clean sharp edge the drawing must correspond, for its interest and expressiveness depend upon its power to suggest differences in surface—those surfaces which flow gradually into one another as well as those in which the transitions are sharp and abrupt.

The student should be very scrupulous about using only the values of the scale, and in the lower left corner of each sheet he should place within half-inch squares examples of each value used on the drawing with its name and symbol indicated.

PLATE XI.

This capital, of the Roman Corinthian order, is in the Museum of the Baths of Diocletian in Rome.

The foliated portions consist of olive acanthus, and the student should carefully study the differences between this and the soft acanthus. It will be noted that the greatest difference is in the subdivision of the edges into leaflets. In the soft acanthus there is always a strong contrast of large and small leaflets and the lobes overlap each other, producing a full rich effect and the general appearance is more like that of a natural leaf. In the olive acanthus the leaflets in one lobe differ slightly from each other in size, are narrower, and bounded by simple curves on either side, where the leaflet of the soft acanthus has the compound curve on one side.

The student may use as many values as he thinks necessary, but he should be conscientious in keeping his values in their scale relations and should place an example of each value used, with its name in one corner of the drawing.

To make a satisfactory drawing of a form so full of intricate detail as this is difficult, as there is a great temptation to put in all one sees. The general instructions for drawing Plate VII are equally applicable here. The student should remember that a drawing is an explanation, but an explanation which can take much for granted.

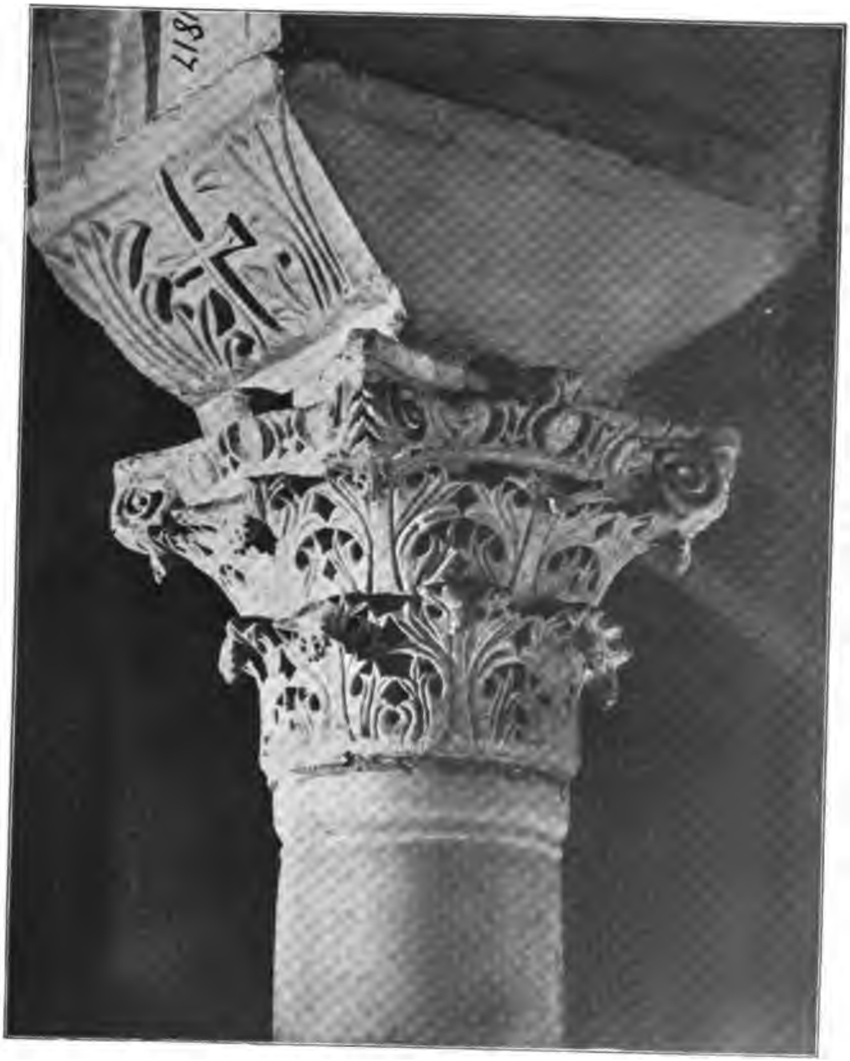


PLATE X. FIG. 2.
Byzantine Capital, from the Church of San Vitale Ravenna.

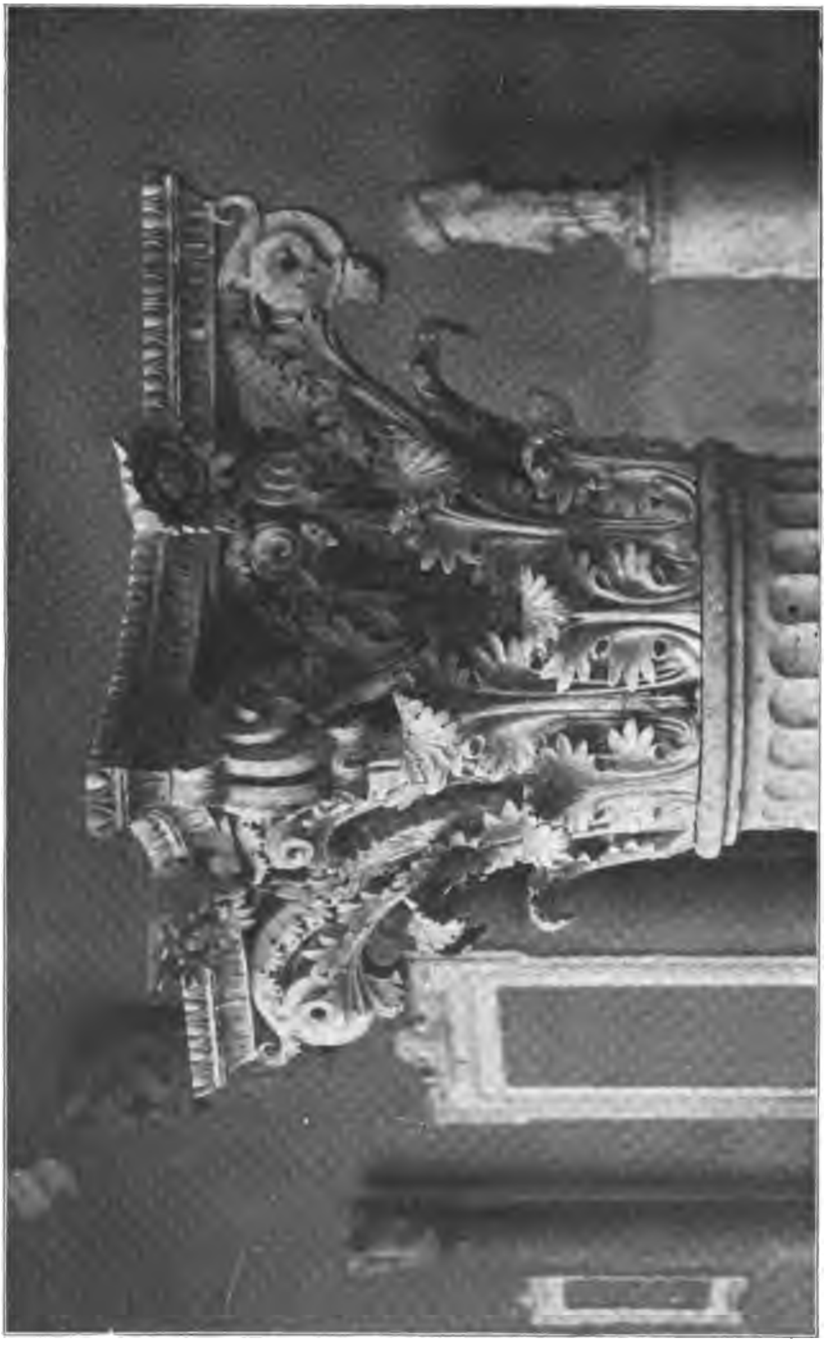


PLATE XI.
Roman Corinthian Capital, from the Baths of Diocletian.

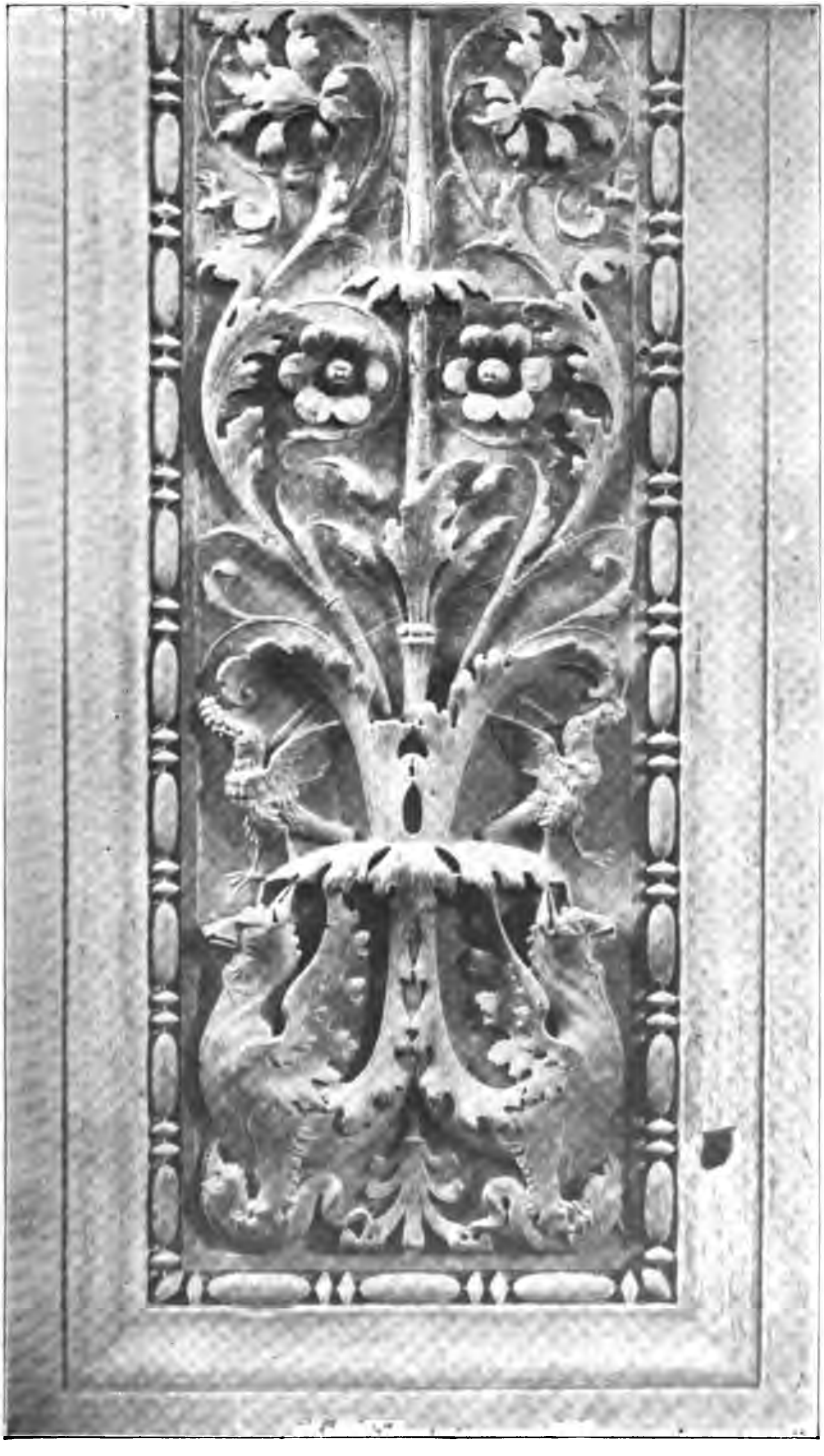


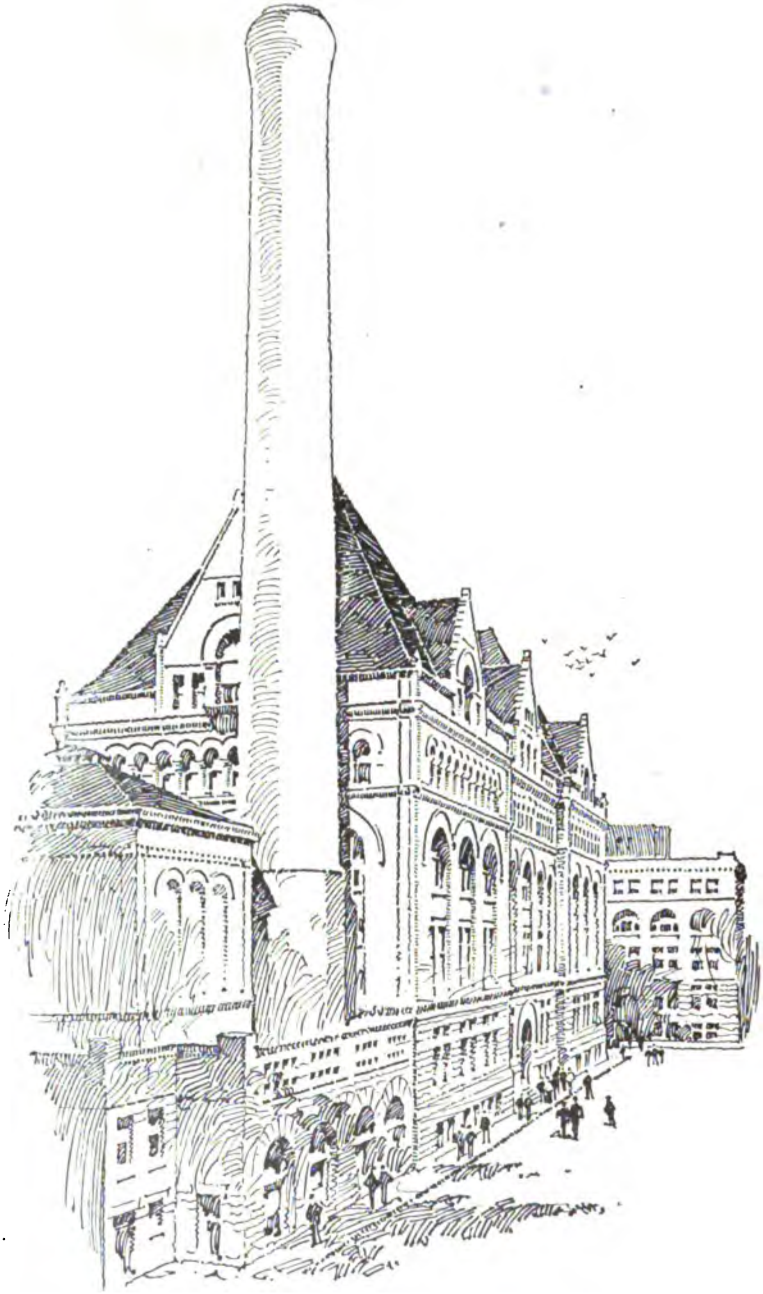
PLATE XII.
Italian Renaissance Pilaster.

For instance, if the carved ornament on the mouldings or at the top of the capital are expressed where they receive full light, they must become more and more vague suggestions and finally disappear in the strong shadows; so the division line between the two mouldings of the abacus may be omitted in shadow and the mind will fill in what the eye does not see. One could go farther and express the detail only for a short space, letting it gradually die away into light or be merely indicated by a line or two, and still the explanation would be sufficient and far less fatiguing to the eye than literal insistence on every detail for the entire length. It is an excellent plan to look at the original, whether a photograph or the real object, with half closed eyes. This helps decidedly to separate the light masses from the darks and shows how much that is in shadow may be omitted.

The smaller lobes on the olive acanthus have no main ribs and lines are carried from the intersection of each leaf toward the base, the section of the leaflet being concave. The section of the leaflets on the soft acanthus is more V-shaped.

PLATE XII.

This is a portion of a pilaster decoration in the Italian Renaissance style. The acanthus is of the soft Roman type, but much more thin and delicate with the eyes cut back almost to the main ribs and a space cut out between each lobe so there is rarely any overlapping of lobes. Lay out construction lines for the scrolls, block in all forms correctly, detailing little by little, so carrying the whole drawing along to the same degree of finish



A Typical Perspective Drawing Rendered in Pen and Ink.

PERSPECTIVE DRAWING.

DEFINITIONS AND GENERAL THEORY.

1. WHEN any object in space is being viewed, rays of light are reflected from all points of its visible surface, and enter the eye of the observer. These rays of light are called **visual rays.** They strike upon the sensitive membrane, called the retina, of the eye, and form an image. It is from this image that the observer receives his impression of the appearance of the object at which he is looking.

2. In Fig. 1, let the triangular card *abc* represent any object in space. The image of it on the retina of the observer's eye will be formed by the visual rays reflected from its surface. These rays form a pyramid or cone which has the observer's eye for its apex, and the object in space for its base.

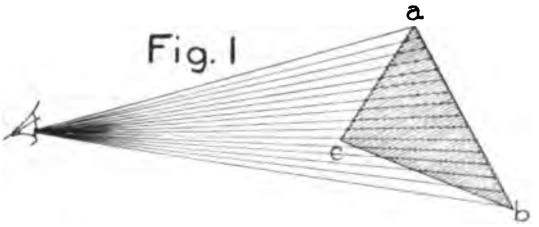


Fig. 1

3. If a transparent plane M, Fig. 2, be placed in such a position that it will intersect the cone of visual rays as shown, the intersection will be a **projection** of the object upon the plane M. It will be noticed that the projecting lines, or **projectors,** instead of being perpendicular to the plane, as is the case in orthographic projection,* are the visual rays which all converge to a single point coincident with the observer's eye.

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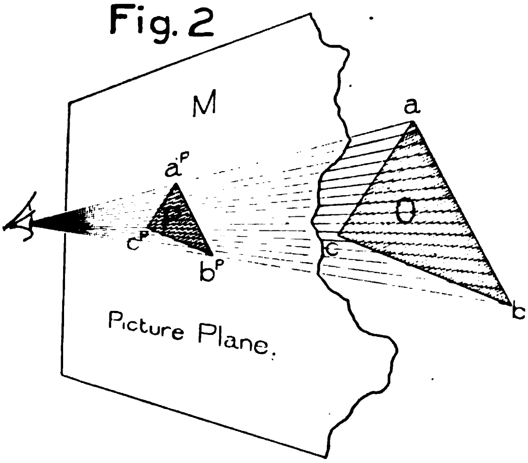
* In orthographic projection an object is represented upon two planes at right angles to each other, by lines drawn perpendicular to these planes from all points on the edges or contour of the object. Such perpendicular lines intersecting the planes give figures which are called projections (*orthographic*) of the object.

4. Every point or line in the projection on the plane M will appear to the observer exactly to cover the corresponding point or line in the object. Thus the observer sees the point a^p in the projection, apparently just coincident with the point a in the object. This must evidently be so, for both the points a^p and a lie on the same visual ray. In the same way the line a^pb^p in the projection must appear to the observer to exactly cover the line ab in the object; and the projection, as a whole, must present to him exactly the same appearance as the object in space.

5. If the projection is supposed to be permanently fixed upon the plane, the object in space may be removed without affecting the image on the retina of the observer's eye, since the visual rays which were originally reflected from the surface of the object are now reflected from the projection on the plane M. In other words, this projection may be used as a substitute for the object in space, and when placed in proper relation to the eye of the observer, will convey to him an impression exactly similar to that which would be produced were he looking at the real object.

Fig. 2



6. A projection such as that just described is known as a **perspective projection** of the object which it represents. The plane on which the perspective projection is made is called the **Picture Plane.** The position of the observer's eye is called the **Station Point,** or **Point of Sight.**

7. It will be seen that the perspective projection of any point in the object, is where the visual ray, through that point, pierces the picture plane.

8. A perspective projection may be defined as the represen-

tation, upon a plane surface, of the *appearance* of objects as seen from some given point of view.

9. Before beginning the study of the construction of the perspective projection, some consideration should be given to phenomena of perspective. One of the most important of these phenomena, and one which is the keynote to the whole science of perspective, has been noticed by everyone. It is the *apparent* diminution in the size of an object as the distance between the object and the eye increases. A railroad train moving over a long, straight track, furnishes a familiar example of this. As the train moves farther and farther away, its dimensions apparently become smaller and smaller, the details grow more and more indistinct, until the whole train appears like a black line crawling over the ground. It will be noticed also, that the speed of the train seems to diminish as it moves away, for the equal distances over which it will travel in a given time, seem less and less as they are taken farther and farther from the eye.

10. In the same way, if several objects having the same dimensions are situated at different distances from the eye, the nearest one appears to be the largest, and the others appear to be smaller and smaller as they are farther and farther away. Take, for illustration, a long, straight row of street-lamps. As one looks along the row, each succeeding lamp is apparently shorter and smaller than the one before. The reason for this can easily be explained. In estimating the size of any object, one most naturally compares it with some other object as a standard or unit. Now, as the observer compares the lamp-posts, one with another, the result will be something as follows (see Fig. 3). If he is looking at the top of No. 1, along the line *ba*, the top of No. 2 is invisible. It is apparently below the top of No. 1, for, in order to see No. 2, he has to lower his eye until he is looking in

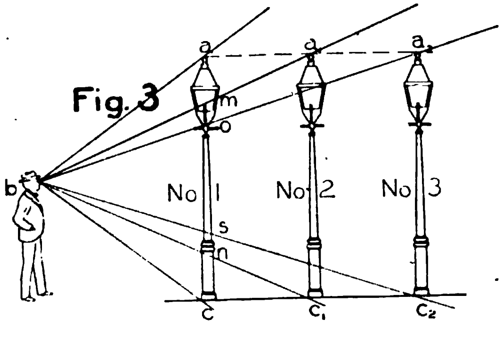


Fig. 3

the direction ba_1. He now sees the top of No. 2, but the top of No. 1 seems some distance above, and he naturally concludes that No. 2 appears shorter than No. 1. As the observer looks at the top of No. 2, No. 3 is still invisible, and, in order to see it, he has to lower his eye still farther. Comparing the bottoms of the posts, he finds the same apparent diminution in size as the distance of the posts from his eye increases. The length of the second post appears only equal to the distance *mn* as measured on the first post, while the length of the third post appears only equal to the distance *os* as measured on post No. 1.

11. In the same way that the lamp-posts appear to diminish in size as they recede from the eye, the parallel lines (a, a_1, a_2, etc., and c, c_1, c_2, etc.) which run along the tops and bottoms of the posts appear to converge as they recede, for the distance between these lines seems less and less as it is taken farther and farther away. At infinity the distance between the lines becomes zero, and the lines appear to meet in a single point. This point is called the **vanishing point** of the lines.

12. If any object, as, for illustration, a cube, is studied, it will be seen that the lines which form its edges may be separated into groups according to their different directions; all lines having the same direction forming one group, and apparently converging to a common vanishing point. Each group of parallel lines is called a **system**, and each line an **element** of the system. For example, in Fig. 4, A, A_1, A_2, and A_3 belong to one group or system; B, B_1, B_2, and B_3, to another; and C, C_1, C_2, and C_3, to a third. Each system has its own vanishing point, towards which all the elements of that system appear to converge. This phenomenon is well illustrated in the parallel lines of a railroad track, or by the horizontal lines which form the courses of a stone wall.

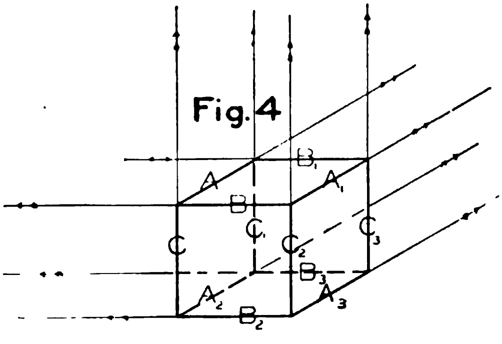


Fig. 4

13. As all lines which belong to the same system appear to meet at the vanishing point of their system, it follows that *if the eye is placed so as to look directly along any line of a system, that line will be seen endwise, and appear as a point exactly covering the vanishing point of the system to which it belongs.*

If, for illustration, the eye glances directly along one of the horizontal lines formed by the courses of a stone wall, this line will be seen as a point, and all the other horizontal lines in the wall will apparently converge towards the point. In other words, the line along which the eye is looking appears to cover the vanishing point of the system to which it belongs. Thus, the vanishing point of any system of lines must lie on that element of the system which enters the observer's eye, and must be at an infinite distance from the observer. Therefore, to find the vanishing point of any system of lines, imagine one of its elements to enter the observer's eye. This element is called the **visual element** of the system, and may often be a purely imaginary line indicating simply the direction in which the vanishing point lies. The vanishing point will always be found on this visual element and at an infinite distance from the observer.

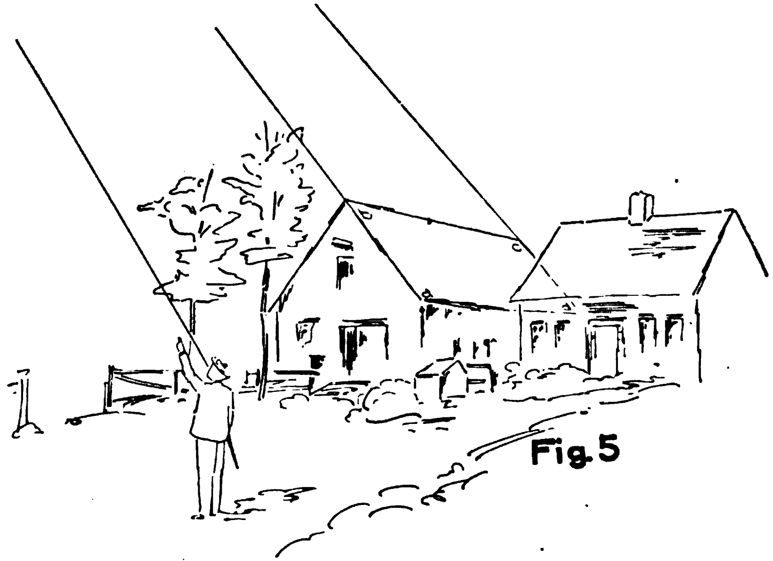


Fig. 5

14. To further illustrate this point, suppose an observer to be viewing the objects in space represented in Fig. 5. He desires

to find the vanishing point for the system of lines parallel to the oblique line *ab* which forms one edge of the roof plane *abcd*. There are two lines in the roof that belong to this system, namely: *ab* and *dc* If he imagines an element of the system to enter his eye, and looks directly along this element, he will be looking in a direction exactly parallel to the line *ab*, and he will be looking directly at the vanishing point of the system (§ 13). This visual element along which he is looking is a purely imaginary line parallel to *ab* and *dc*. All lines in the object belonging to this system will appear to converge towards a point situated on the line along which he is looking, and at an infinite distance from him.

This phenomenon is of great importance, and is the foundation of most of the operations in making a perspective drawing.

15. The word "vanish" as used in perspective always implies a recession. Thus, a line that vanishes upward, slopes upward as it *recedes* from the observer; a line that vanishes to the right, slopes to the right as it *recedes* from the observer.

16. It follows from paragraphs 13 and 14 that any system of lines that vanishes upward, will have its vanishing point above the observer's eye. Similarly, any system vanishing downward, will have its vanishing point below the observer's eye; any system vanishing to the right, will have its vanishing point to the right of the observer's eye; and any system vanishing to the left, will have its vanishing point to the left of the observer's eye. Any system of horizontal lines will have its vanishing point on a level with the observer's eye, and a system of vertical lines will have its vanishing point vertically in line with the observer's eye.

17. All planes that are parallel to one another are said to belong to the same system, each plane being called an element of the system.

All the planes of one system appear to approach one another as they recede from the eye, and to meet at infinity in a single straight line called the **vanishing trace** of the system. Thus, the upper and lower faces of a cube seen in space, will appear to converge toward a straight line at infinity.

18. If the eye is so placed as to look directly along one of

the planes of a system, that plane will be seen edgewise, and will appear as a single straight line exactly covering the vanishing trace of the system to which it belongs. The plane of any system that passes through the observer's eye is called the **visual plane** of that system.

19. From § 18, it follows that the vanishing trace of a system of planes that vanishes upward, will be found above the level of the eye, while the vanishing trace of a system of planes vanishing downward, will be found below the level of the eye. The vanishing trace of a system of vertical planes will be a vertical line; and of a system of horizontal planes, a horizontal line, exactly on a level with the observer's eye.

20. The vanishing trace of the system of horizontal planes is called the **horizon.**

The visual plane of the horizontal system is called the **plane of the horizon.** The plane of the horizon is a most important one in the construction of a perspective projection.

21. From the foregoing discussion the truth of the following statements will be evident. They may be called the Five Axioms of Perspective.

(*a*) *All the lines of one system appear to converge and to meet at an infinite distance from the observer's eye, in a single point called the vanishing point of the system.*

(*b*) *All the planes of one system appear to converge as they recede from the eye, and to meet at an infinite distance from the observer, in a single straight line called the vanishing trace of the system.*

(*c*) *Any line lying in a plane will have its vanishing point somewhere in the vanishing trace of the plane in which it lies.*

(*d*) *The vanishing trace of any plane must pass through the vanishing points of all lines that lie in it. Thus, since the vanishing trace of a plane is a straight line* (§ 18), *the vanishing points of any two lines lying in a plane will determine the vanishing trace of the system to which the plane belongs.*

(*e*) *As the intersection of two planes is a line lying in both, the vanishing point of this intersection must lie in the vanishing traces of both planes, and hence, at the point where the vanishing traces of the two planes cross. In other words, the vanishing point* *of the intersection of two planes must lie at the intersection of the vanishing traces of the two planes.*

22. The five axioms in the last paragraph are the statements of purely imaginary conditions which appear to exist, but in reality do not. Thus, parallel lines appear to converge and to meet at a point at infinity, but in reality they are exactly the same distance apart throughout their length. Parallel planes appear to converge as they recede, but this is a purely apparent condition, and not a reality; the real distance between the planes does not change.

23. The perspective projection represents by real conditions the purely imaginary conditions that appear to exist in space.

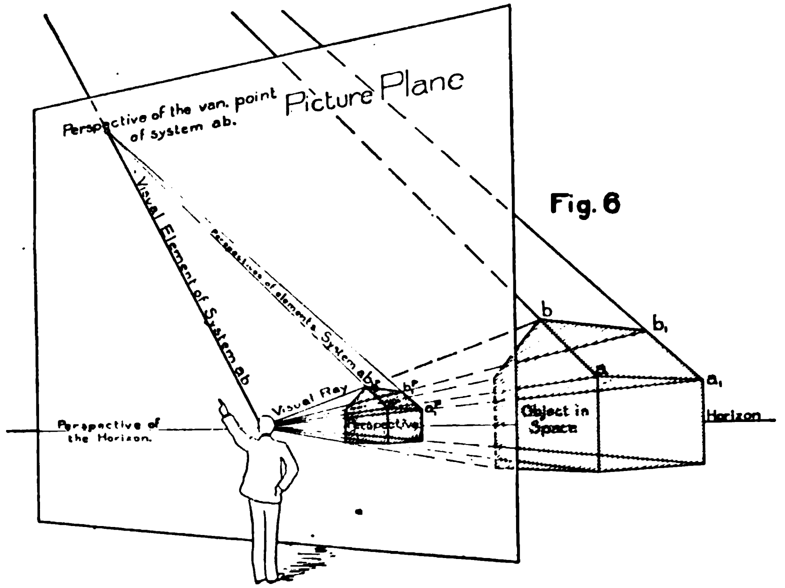

Picture Plane
Perspective of the van. point of system ab.
Visual Element of System ab
Perspectives of elements System ab
Visual Ray
b
b_1
a
a_1
b^p
a^p
Perspective
Perspective of the Horizon.
Object in Space
Horizon

Fig. 6

Thus, the apparent convergence of lines in space is represented by a real convergence in the perspective projection. Again, the vanishing point of a system of lines is a purely imaginary point which does not exist. But this imaginary point is represented in perspective projection by a real point on the picture plane.

From § 14, the vanishing point of any system of lines lies upon the visual element of that system. This visual element may be considered to be the visual ray which projects the vanishing point to the observer's eye. Hence, from § 7, the intersection of this visual element with the picture plane will be the perspective of the vanishing point of the system to which it belongs. This is illustrated in Fig. 6. The object in space is shown on the right of the figure. If the observer wishes to find the vanishing point of the oblique line ab in the object in space, he imagines a line parallel to ab to enter his eye, and looks along this line (§ 13). Where this line along which he is looking pierces the picture plane, will be the perspective of the vanishing point. Furthermore, the perspective of the line ab has been found by drawing the visual rays from a and b respectively, and finding where these rays pierce the picture plane (§ 7). These points are respectively, a^P and b^P, and the straight line drawn between a^P and b^P is the perspective of the line ab. The perspective of the line a_1b_1 which is parallel to ab, has been found in a similar way, and it will be noticed that its perspective projection (a_1^P b_1^P) actually converges towards a^Pb^P in such a manner that if these two lines are produced they will actually meet at the perspective of the vanishing point of their system.

NOTE.— *It is evident that the perspective of a straight line will always be a straight line, the extreme points of which are the perspectives of the extremities of the given line.*

24. Thus, the five axioms of perspective may be applied to Perspective Projection as follows:—

(*a*) Parallel lines do converge and meet at the vanishing point of their system.

(*b*) Parallel planes do converge and meet at the vanishing trace of their system.

(*c*) The vanishing point of any line lying in a plane will be found in the vanishing trace of the plane.

Therefore, the vanishing points of all horizontal lines will be found in the horizon (§ 20).

(*d*) The vanishing trace of any plane will be determined by the vanishing points of any two lines that lie in it, and must contain the vanishing points of all lines that lie in it.

(*e*) The vanishing point of the intersection of two planes will be found at the intersections of the vanishing traces of the two planes.

To the five axioms of perspective projection already stated may be added the following three truths concerning the construction of the perspective projection: —

(*f*) The perspective of any point in space is where the visual ray through the point pierces that picture plane (§ 7).

(*g*) The perspective of the vanishing point of any system of lines is where the visual element of that system pierces the picture plane.

Rule for finding the perspective of the vanishing point of any system of lines: — Draw an element of the system through the observer's eye, and find where it pierces the picture plane.

(*h*) Any point, line, or surface which lies in the picture plane will be its own perspective, and show in its true size and shape.

25. Knowing how to find the perspective of any point, and how to find the vanishing point of any system of lines, any problem in perspective may be solved. Therefore, it may be said that the whole process of making a perspective projection reduces itself to the problem of finding where a line pierces a plane.

Before proceeding farther, the student should review the first twenty-five paragraphs by answering carefully the following questions: —

(1) What does a perspective projection represent?

(2) What is a visual ray?

(3) How is a perspective projection formed?

(4) How does a perspective projection differ from an orthographic projection?

(5) What is the plane called on which the perspective projection is made?

(6) What is meant by the term Station Point?

(7) What is the most important phenomenon of perspective

(8) What is meant by a system of lines?

(9) What is meant by a system of planes?

(10) What is a visual element?

(11) Define vanishing point.

(12) Define vanishing trace.

(13) Describe the position of the vanishing point of any system of lines.

(14) Give the five axioms of perspective.

(15) Do parallel lines in space really converge?

(16) Do the perspective projections of parallel lines really converge?

(17) Where will the perspective projections of parallel lines meet?

(18) How is the perspective of any point found?

(19) How is the perspective of the vanishing point of any system of lines found?

(20) What will be the perspective of a straight line?

(21) What is meant by the horizon?

(22) What is meant by the plane of the horizon?

THE PLANES OF PROJECTION.

26. Two planes of projection at right angles to one another, one vertical and the other horizontal, are used in making a perspective. In Fig. 7 these two planes are shown in oblique projection. The vertical plane is the picture plane (§ 6 and Fig. 7) on which the perspective projection is made, and corresponds exactly to the vertical plane, or vertical coordinate used in orthographic projections.

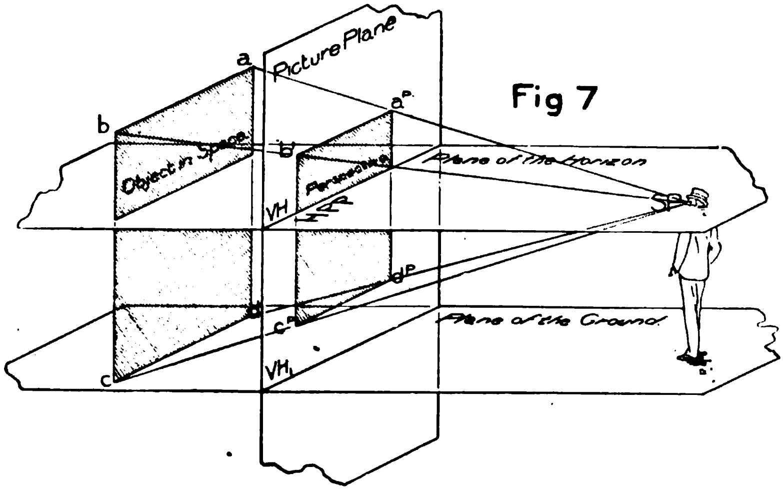


Fig 7

27. The horizontal plane, or plane of the horizon (§ 20 and Fig. 7), *always passes through the assumed position of the observer's eye*, and corresponds exactly to the horizontal plane or horizontal coordinate used in orthographic projections.

28. All points, lines, surfaces, or solids in space, the perspective projections of which are to be found, are represented by their orthographic projections on these two planes, and their perspectives are determined from these projections.

29. Besides these two principal planes of projection, a third plane is used to represent the plane on which the object is supposed to rest (Fig. 7). This third plane is horizontal, and is called the plane of the ground. Its relation to the plane of the horizon determines the nature of the perspective projection. To illustrate: The observer's eye must *always* be in the plane of the horizon (§ 27), while the object, the perspective of which is to be made, is usually supposed to rest upon the plane of the ground. In most cases the plane of the ground will also be the plane on which the observer is supposed to stand, but this will not always be true. The observer may be standing at a much higher level than the plane on which the object rests, or he may be standing below that plane. It is evident, therefore, that if the plane of the ground is chosen far below the plane of the horizon, the observer's eye will be far above the object, and the resulting perspective projection will be a "bird's-eye view." If, on the other hand, the plane of the ground is chosen above the plane of the horizon, the observer's eye will be below the object, and the resulting perspective projection will show the object as though being viewed from below. This has sometimes been called a "worm's-eye view," or a "toad's-eye view."

Usually the plane of the ground is chosen so that the distance between it and the plane of the horizon is about equal (at the scale of the drawing) to the height of a man. This is the position indicated in Fig. 7, and the resulting perspective will show the object as though seen by a man standing on the plane on which the object rests.

30. The intersection of the *picture plane* and the *plane of the horizon* corresponds to the *ground line* used in the study of projections, in Mechanical Drawing. For more advanced work, how-

ever, there is some objection to this term. The intersection of the two coordinate planes has really no connection with the ground, and if the term "ground line" is used, it is apt to result in a confusion between the intersection of the two coordinate planes, and the intersection of the auxiliary plane of the ground, with the picture plane.

31. The intersection of the two coordinate planes is usually lettered VH on the picture plane, and HPP on the plane of the horizon. (See Fig. 7.) That is to say: When the vertical plane is being considered, VH represents the intersection of that plane with the plane of the horizon. It should also be considered as the *vertical projection of the plane of the horizon.* See Mechanical Drawing Part III, page 5, paragraph in italics. All points, lines, or surfaces lying in the plane of the horizon will have their *vertical projection* in VH.

32. On the other hand, when the horizontal plane is being considered, HPP represents the intersection of the two planes, and also the *horizontal projection of the picture plane.* All points, lines, or surfaces in the picture plane will have their *horizontal projections* in HPP. Thus, instead of considering the intersection of the two coordinate planes a single line, it should be considered the coincidence of two lines, i.e.: First, the vertical projection of the plane of the horizon; second, the horizontal projection of the picture plane.

33. The plane of the ground is always represented by its intersection with the picture plane (see VH_1 Fig. 7). Its only use is to determine the relation between the plâne of the horizon and the plane on which the object rests (§ 29). The true distance between these two planes is always shown by the distance between VH and VH_1 as drawn on the picture plane.

34. To find the perspective of a point determined by its vertical and horizontal projections.

Fig. 8 is an oblique projection showing the two coordinate planes at right angles to each other. The assumed position of the plane of the ground is indicated by its **vertical trace** (VH_1).

NOTE. — The *vertical trace* of any plane is the intersection of that plane with the vertical coordinate. The *horizontal trace* of any plane is the intersection of that plane with the horizontal coordinate.

The assumed position of the station point is indicated by its two projections, SP^V and SP^H. Since the station point lies in the plane of the horizon (§ 27), it is evident that its true position must coincide with SP^H, and that (§ 31) its vertical projection must be found in VH, as indicated in the figure. Let the point *a* represent any point in space. The perspective of the point *a* will be at a^P, where a visual ray through the point *a* pierces the picture plane (§ 24). We may find a^P in the following manner, by using the orthographic projections of the point a^P, instead of the point itself. a^H represents the *horizontal projection*, and a^V represents the *vertical projection* of the point *a*. A line drawn from the *vertical projection* of the point *a* to the *vertical projection* of the station point, will represent the *vertical projection of the visual ray*, which passes through the point *a*. In Fig. 8 this vertical projection is represented by the line drawn on the picture plane from a^V to SP^V.

A line drawn from the *horizontal projection* of *a* to the *horizontal projection* of the station point will represent the *horizontal projection of the visual ray*, which passes through the point *a*. In Fig. 8, this horizontal projection is represented by the line drawn on the plane of the horizon from a^H to SP^H. Thus we have, drawn upon the planes of projection, the vertical and horizontal projections of the point *a*, and the vertical and horizontal projections of the visual ray passing between the point *a* and the station point.

35. We must now find the intersection of the visual ray with the picture plane. This intersection will be a point in the picture plane. It is evident that its vertical projection must coincide with the intersection itself, and that its horizontal projection must be in HPP (§ 32). But this intersection must also be on the visual ray through the point *a*, and consequently the horizontal projection of this intersection must be on the horizontal projection of the visual ray. Therefore, the horizontal projection of this intersection must be the point m^H, where the line between

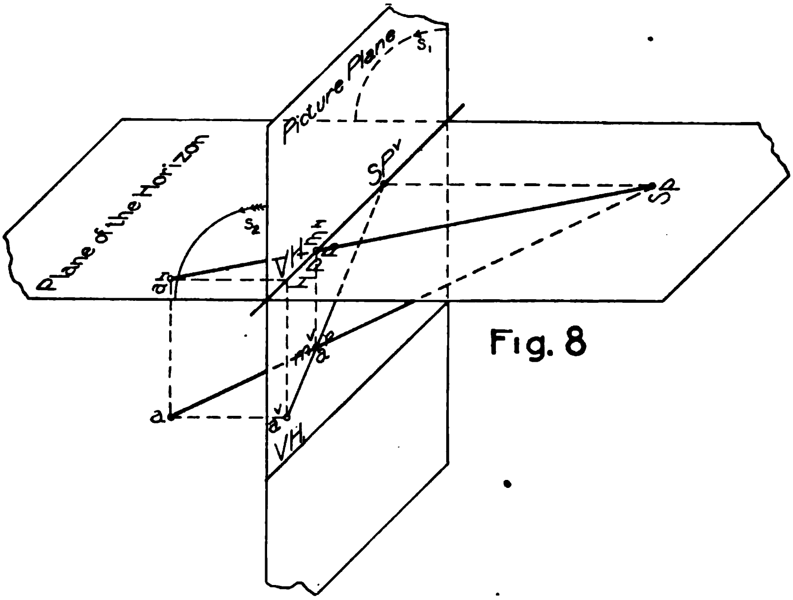


Fig. 8

Fig. 9

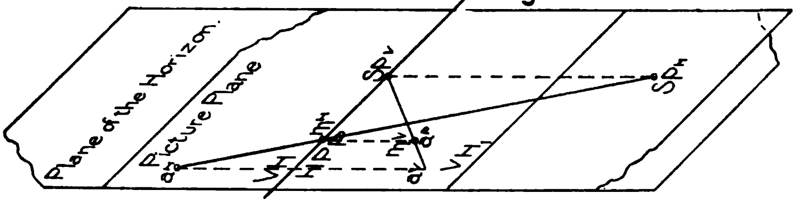
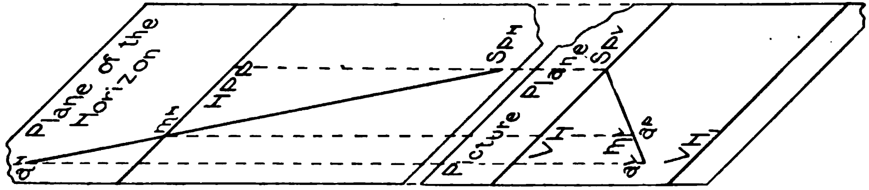


Fig. 9a



SP^H and a^H crosses HPP. The vertical projection of this intersection must be vertically in line with this point, and on the line drawn between SP^V and a^V, and hence at m^V. Since the vertical projection of the intersection coincides with the intersection itself, a^P (coincident with m^V) must be the perspective of the point a.

36. This is the method of finding the perspective of any point, having given the vertical and horizontal projections of the point and of the station point. The method may be stated briefly as follows: —

Draw through the horizontal projection of the point and the horizontal projection of the station point, a line representing the horizontal projection of the visual ray, which passes through the point. Through the intersection of this line with HPP, draw a vertical line. The perspective of the point will be found where this vertical line crosses the vertical projection of the visual ray, drawn through SP^V and a^V.

37. It would evidently be inconvenient to work upon two planes at right angles to one another, as shown in Fig. 8. To avoid this, and to make it possible to work upon a plane surface, the picture plane (or vertical coordinate) is supposed to be revolved about its intersection with the plane of the horizon, until the two coincide and form one surface. The direction of this revolution is indicated by the arrows s_1 and s_2. After revolution, the two coordinate planes will coincide, and the vertical and horizontal projections overlap one another, as indicated in Fig. 9.

It will be noticed that the coincidence of the two planes in no way interferes with the method given in § 36, of finding the perspective (a^P) of the point a, from the vertical and horizontal projections of the point. Thus, the horizontal projection of the visual ray through the point will be seen, drawn from SP^H to a^H, and intersecting HPP in the point m^H. The vertical projection of the visual ray through the point will be seen passing from SP^V to a^V. And a^P is found upon the vertical projection of the visual ray, directly under m^H.

It will readily be understood that in a complicated problem, the overlapping of the vertical and horizontal projections might result in some confusion. It is, therefore, usually customary, after having revolved the two coordinate planes into the position shown in Fig. 9, to slide them apart in a direction *perpendicular to their line of intersection*, until the two planes occupy a position similar to that shown in Fig. 9a.

38. It will be remembered from the course on projections which the student is supposed to have taken, that *horizontal projections must always be compared with horizontal, and never with vertical projections*, and that in the same way, *vertical projections must always be compared with vertical, and never with horizontal projections.* It is evident that in sliding the planes apart, the relations between the projections on the vertical plane will not be disturbed, nor will the relations between the projections on the horizontal plane, and consequently it will make no difference how far apart the two coordinate planes are drawn, provided that horizontal and vertical projections of the same points are always kept in line. Thus, in Fig. 9a, it will be seen that in drawing the planes apart, a^V has been kept in line with a^H, m^V with m^H, SP^V with SP^H, etc.

39. It will be observed that in sliding the planes apart, their line of intersection has been separated into its two projections (§§ 31 and 32). HPP, being on the plane of the horizon or horizontal coordinate, is the *horizontal projection of the intersection* of the two planes, while VH, being on the picture plane or vertical coordinate, is the *vertical projection of the intersection* of the two planes. In the original position of the planes (Fig. 9) these two projections were coincident. The distance between HPP and VH always represents the distance through which the planes have been slid. This distance is immaterial, and will have *no effect* on the perspective drawing. VH_1 represents the vertical trace of the plane of the ground.

In this figure, as in the case of Fig. 9, the student should follow through the construction of the perspective of the point *a*, applying the method of § 36.

40. Fig. 10 shows the position of the two coordinate planes and of the plane of the ground, as they are usually represented on the drawing board in making a perspective drawing. It is essentially the same thing as Fig. 9a, except that the latter was

shown in oblique projection in order that its development from the original position of the planes (Fig. 8) might be followed more readily. The two coordinate planes are supposed to lie in the plane of the paper.

HPP represents the horizontal projection of the picture plane, and VH represents the vertical projection of the plane of the horizon.

As horizontal projections are never compared with vertical projections (§ 38), HPP may be drawn as far from, or as near, VH as desired, without in any way affecting the resulting perspective drawing. HPP and VH were coincident in Fig. 9, and the distance between them in Fig. 10 simply shows the distance that the two planes have been slid apart, as illustrated in Fig. 9a. As already stated, this distance is immaterial, and may be made whatever is most convenient, according to the nature of the problem.

If HPP should be placed nearer the top of the sheet, a^H and SP^H, both being horizontal projections, would follow it, the relation between these horizontal projections always being preserved.

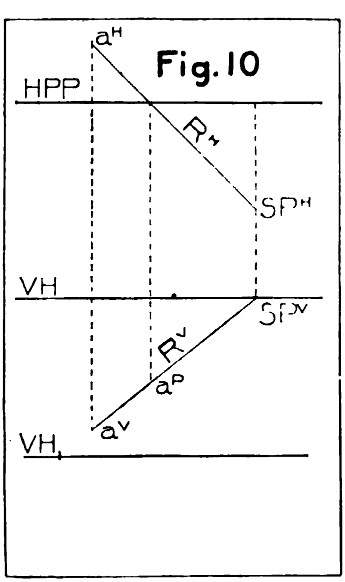


Fig. 10

On the other hand, SP^V, a^V, a^P, VH, and VH$_1$, all being projections on the vertical plane, must preserve their relation with one another, and will in no way be affected if the group of projections on the horizontal coordinate is moved nearer or farther away. It must be borne in mind, however, that, in all cases, the vertical and horizontal projections of corresponding points must be kept vertically in line. Thus, a^H must always be vertically in line with a^V. The vertical distance between these two projections does not matter, provided the distance from a^H to HPP, or the distance from a^V to VH, is not changed. This point cannot be too strongly emphasized.

41. Suppose it is desired to determine from Fig. 10 how far the station point lies in front of the picture plane. This is a horizontal distance, and therefore will be shown by the distance between the horizontal projection of the station point and the horizontal projection of the picture plane, or, in other words, by the distance between SP^H and HPP.

42. The point a is a certain distance above or below the plane of the horizon. This is a *vertical distance*, and will be shown by the distance between the *vertical projection* of the point a and the *vertical projection* of the plane of the horizon; in other words, by the distance between a^V and VH. It will be seen that in Fig. 10 the point a lies below the plane of the horizon.

43. If it be desired to find how far in front or behind the picture plane the point a lies, this is a *horizontal distance*, and will be shown by the distance between the *horizontal projection* of the picture plane and *horizontal projection* of the point a, that is, by the distance between HPP and a^H. In Fig. 10 the point a lies behind the picture plane.

44. The distance between the plane of the ground and the plane of the horizon is a vertical distance, and will be shown by the distance between the vertical projection of the plane of the horizon and the vertical projection of the plane of the ground; i.e., the distance between VH and VH_1. The distance between the observer's eye and the plane of the ground is also a vertical distance, and will be shown by the distance between SP^V and VH_1; but as SP^V must always be found in VH, the distance of the observer's eye above the plane of the ground will always be shown by the distance between VH and VH_1.

45. To find the perspective of the point a, Fig. 10, draw the visual ray through the point, and find where this visual ray pierces the picture plane (§ 24*f*). The horizontal projection of the visual ray is shown by the line R^H drawn through the horizontal projection SP^H of the observer's eye and the horizontal projection a^H of the point a. The vertical projection of the visual ray is shown by the line R^V drawn through the vertical projection SP^V of the observer's eye and the vertical projection a^V of the point a. This visual ray pierces the picture plane at the point a^P on R^V vertically in line with the point where

R^H crosses HPP (§§ 35 and 36). a^P is the perspective of the point a.

NOTE. — To find where any line, represented by its horizontal and vertical projections, pierces the picture plane, is one of the most used and most important problems in perspective projection. The point where any line pierces the picture plane will always be found on the vertical projection of the line, vertically above or below the point where the horizontal projection of the line crosses HPP (§§ 35 and 36).

NOTATION.

46. In order to avoid confusion between the vertical, horizontal, and perspective projections of the points and lines in the drawing, it becomes necessary to adopt some systematic method of lettering the different points and lines. The following method will be found convenient, and has been adopted in these notes.

If the student will letter each point or line as it is found, in accordance with this notation, he will be able to read his drawings at a glance, and any desired projection of a point or line may be recognized instantly.

The *picture plane* (or vertical coordinate) is indicated by the capital letters PP.

The *plane of the horizon* (or horizontal coordinate) is indicated by the capital letter H.

A *point* in space is indicated by a small letter.

The same small letter with an index ^{V}, ^{H}, or ^{P}, indicates its *vertical*, *horizontal*, or *perspective projection*, respectively.

A *line* in space is indicated by a capital letter, usually one of the first letters in the alphabet.

The same capital letter with an index ^{V}, ^{H}, or ^{P}, indicates its *vertical*, *horizontal*, or *perspective projection*, respectively.

All lines which belong to the same system may be designated by the same letter, the different lines being distinguished by the subordinate $_1$, $_2$, $_3$, etc., placed after the letter.

The *trace of a plane upon the picture plane* is indicated by a capital letter (usually one of the last letters in the alphabet) with a capital V placed before it.

The same letter preceded by a capital H *indicates the trace of the plane upon the horizontal coordinate.*

The *perspective of the vanishing trace of a system of planes* is indicated by a capital letter preceded by a capital T.

The *perspective of the vanishing point of a system of lines* is indicated by a small v with an index corresponding to the letter of the lines which belong to the system.

PP = vertical coordinate, or picture plane.

HPP = horizontal trace of the vertical coordinate, or picture plane.

H = horizontal coordinate, or plane of the horizon.

VH = vertical trace of the horizontal coordinate, or plane of the horizon.

H_1 = plane of the ground.

VH_1 = vertical trace of the plane of the ground.

a = point in space.

a^V = vertical projection of the point.

a^H = horizontal projection of the point.

a^P = perspective projection of the point.

A = line in space.

A^V = vertical projection of the line.

A^P = perspective projection of the line.

VS = trace of the plane S upon PP (vertical trace).

HS = trace of the plane S upon H (horizontal trace).

TS = perspective of the vanishing trace of the plane S. (See Note 1 below.)

v^A = perspective of the vanishing point of a system of lines, the elements of which are lettered A_1, A_2, A_3, A_4, etc. (See Note 2 below.)

Note 1. — A plane in space may also be designated by the letters of any two lines which lie in it. Thus, the plane AB would be a plane determined by the two lines A and B. TAB would indicate the perspective of the vanishing trace of the plane.

Note 2. — A straight line may be designated by the letters of any two points which lie in it. Thus, the line ab would be a straight line determined by the two points a and b. v^{ab} would indicate the perspective of the vanishing point of the line. It is sometimes convenient to use this notation in place of the general one.

ELEMENTARY PROBLEMS.

47. PROBLEM I. Fig. 11. **To find the perspective of a point. The point to be situated ¼″ behind the picture plane, and ⅛″ above the plane of the horizon. The observer's eye to be ½″ in front of the picture plane.**

First assume HPP and VH (§ 40). These lines may be drawn anywhere on the paper, HPP usually being placed some distance above VH, in order to avoid confusion between horizontal and vertical projections. The position of the point with respect to the coordinate planes must now be established by means of its vertical and horizontal projections. a^V located ⅛″ above VH will represent the vertical projection of the point. Its horizontal projection must be vertically in line with a^V; and since the point is to be ¼″ behind the picture plane, its horizontal projection must be ¼″ behind the horizontal projection of the picture plane, i.e., ¼″ behind HPP. Next establish the position of the observer's eye, or station point. Its vertical projection (SP^V) may be assumed anywhere in VH. Its horizontal projection (SP^H) must be vertically in line with SP^V and ½″ in front of HPP. The perspective of the point a will be where the visual ray through the point pierces the picture plane. A line R^H drawn through SP^H and a^H will be the horizontal projection of this visual ray. Its vertical projection will be the line R^V drawn through SP^V and a^V. The perspective a^P of the point will be found on R^V vertically in line with the intersection of R^H and HPP (§ 45, note). Compare with the construction shown in Fig. 10 and Fig 8.

Fig. 11

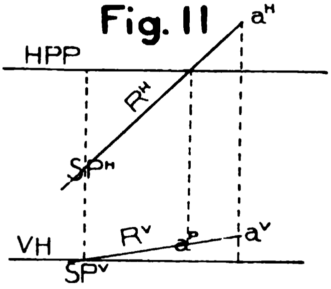
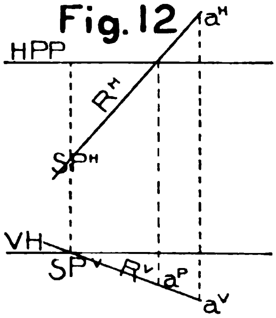


Fig. 12



48. Figs. 12, 13, and 14 illustrate this same problem.

In Fig. 12, the point *a*, as shown by its vertical and horizontal projections, is situated $\frac{1}{4}''$ *below* the plane of the horizon and $\frac{1}{4}''$ ***behind*** the picture plane. a^P is the perspective of the point.

Fig. 13

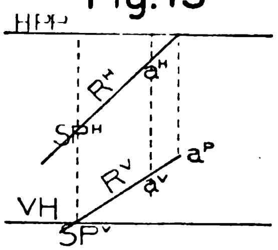
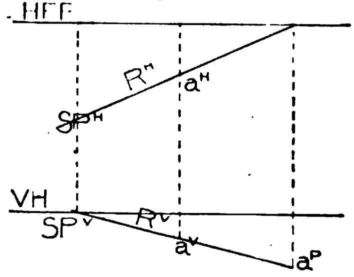


Fig. 14

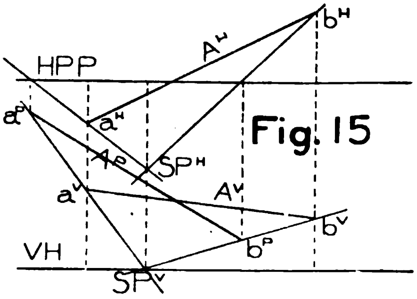


In Fig. 13, the point *a* is $\frac{1}{4}''$ *above* the plane of the horizon and $\frac{1}{8}''$ *in front* of the picture plane. a^P is its perspective.

In Fig. 14, the point *a* is $\frac{1}{8}''$ *below* the plane of the horizon and $\frac{1}{4}''$ *in front* of the picture plane. a^P is its perspective.

49. PROBLEM II. Fig. 15. **To find the perspective of a line, the line being determined by its vertical and horizontal projections.**

Let HPP and VH be given as indicated in the figure. Let A^H represent the horizontal projection of the line, its two extremities being represented by a^H and b^H, respectively. Similarly, let A^V be the vertical projection of the line, a^V and b^V being the vertical projections of its extremities. Let the position of the observer's eye be as indicated by SP^V and SP^H.



The perspective of the point *a* has been found by Problem I. at a^P. The perspective of the point *b* has been found by Problem I. at b^P. The line (A^P), joining a^P and b^P, will be the perspective of the given line. (See note under § 23.)

50. PROBLEM III. Fig. 16. **Having given the vertical and horizontal projection of any line, to find the perspective of its vanishing point.**

Let the line be given by its vertical and horizontal projections (A^V and A^H), as indicated in the figure. SP^V and SP^H represent the position of the observer's eye. To find the perspective of the vanishing point of any line, draw through the observer's eye an element of the system to which the line belongs, and find where this element pierces the picture plane (§ 24 *g*). Through SP^H draw A_1^H parallel to AH, and through SP^V draw A_1^V parallel to A^V. A_1^H and A_1^V represent the two projections of a line passing through the observer's eye and parallel to A^HA^V. This line pierces the picture plane at v^A, giving the perspective of the required vanishing point (§ 45, note). The perspectives of all lines parallel to A^VA^H will meet at v^A.

Fig. 16

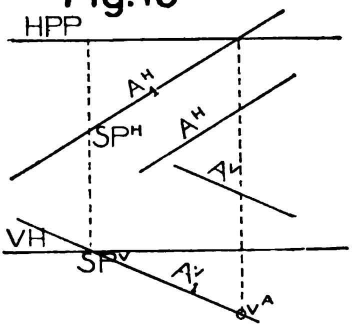


Fig. 17

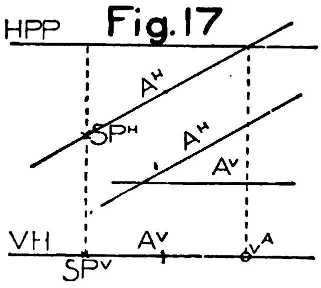
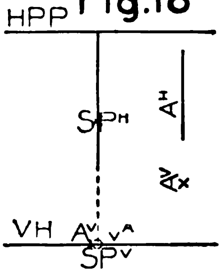


Fig. 18



Figs. 17 and 18 illustrate this same problem.

51. In Fig. 17, the line, as shown by its two projections, is a horizontal one; hence, A_1^V drawn through SP^V coincides with VH, and the vanishing point for the system of the lines must be found on VH at v^A, as indicated (§ 24 *c*).

NOTE. — Systems of lines which vanish upward will have their vanishing points above VH. Systems of lines which vanish downward will have their vanishing points below VH (§ 16).

52. In Fig. 18, the given line is perpendicular to the picture plane; hence, $A_1{}^V$ must be a point coincident with SP^V; and as v^A will always be found on $A_1{}^V$, the vanishing point of the line must coincide with SP^V.

NOTE. — In a perspective drawing, the vanishing point for a system of lines perpendicular to the picture plane will always coincide with the vertical projection of the observer's eye.

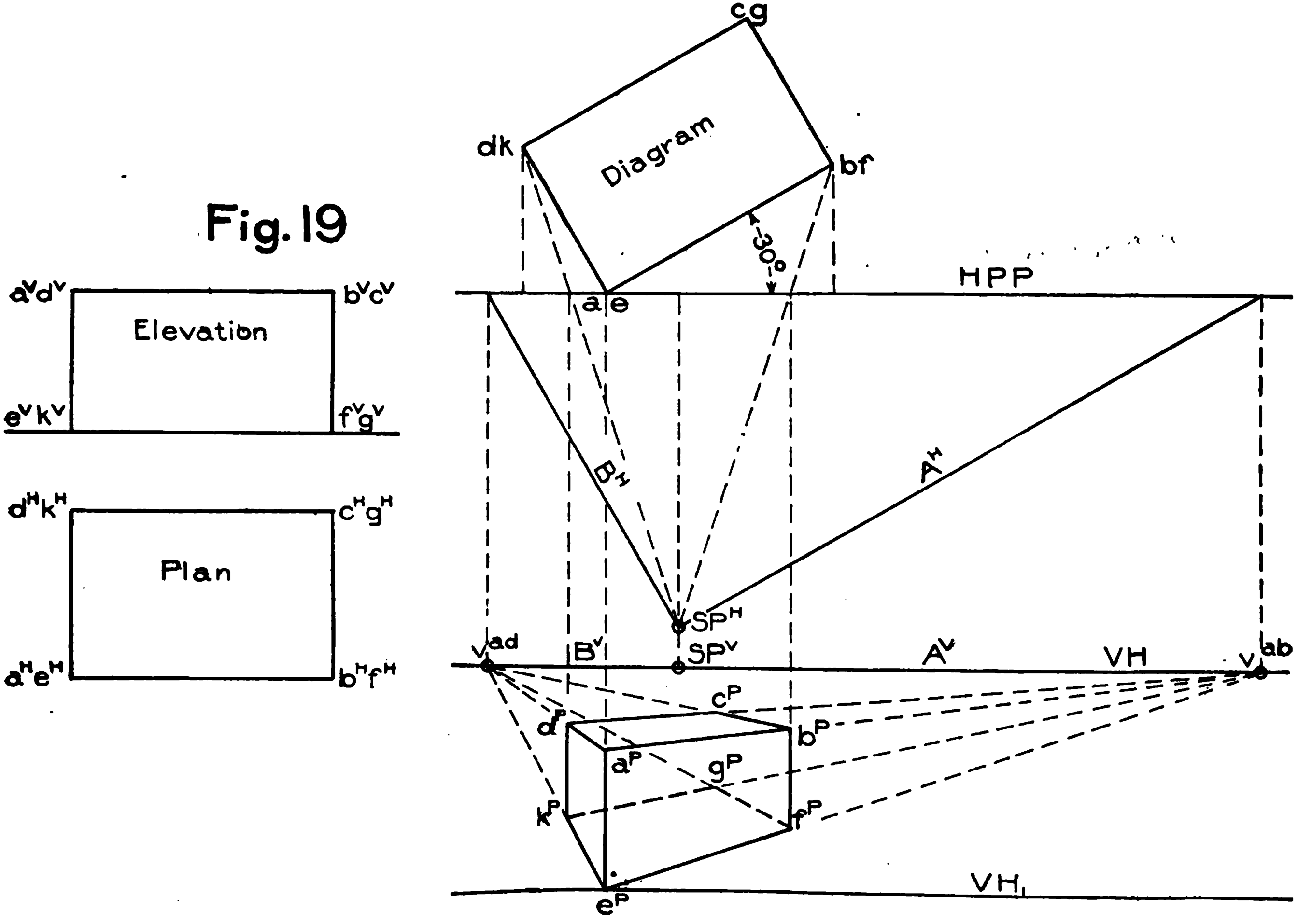
METHOD OF THE REVOLVED PLAN.

53. PROBLEM IV. Fig. 19. **To find the perspective of a rectangular block resting upon a horizontal plane 1" below the level of the eye, and turned so that the long side of the block makes an angle of 30° with the picture plane.**

The block is shown in plan and elevation at the left of the figure. The first step will be to make an auxiliary horizontal projection of the block on the plane of the horizon, showing the exact position of the block as it is to be seen in the perspective projection. This auxiliary horizontal projection is really a revolved plan of the object, and is called a **Diagram.** It is the general rule, in making a perspective projection, to place the object behind the picture plane with one of its principal vertical lines lying in the picture plane (24 *h*). HPP is usually drawn near the upper edge of the paper, leaving just room enough behind to place the auxiliary plan or diagram. In the figure the diagram is shown in the required position, i.e., with one of its long sides (*abfe*) making an angle of 30° with the picture plane. The vertical edge (*ae*) of the block is supposed to lie in the picture plane. VH may now be drawn parallel to HPP at any convenient distance from it, as indicated. VH_1, the vertical trace of the plane on which the block is supposed to rest, should be assumed in accordance with the given data, i.e., 1" below VH (§ 44).

The position of the observer's eye should next be established. SP^H is its horizontal projection, and shows by its distance from HPP the distance in front of the picture plane at which the observer is supposed to stand. SP^V is its vertical projection, and must always be found in VH. In this problem the station point is 1½" in front of the picture plane.

Fig. 19


cg
dk
Diagram
bf
30°
HPP
$a^V d^V$
$b^V c^V$
Elevation
$e^V k^V$
$f^V g^V$
$d^H k^H$
$c^H g^H$
Plan
$a^H e^H$
$b^H f^H$
a
e
B^H
A^H
SP^H
V^{ad}
B^V
SP^V
A^V
VH
V^{ab}
c^P
d^P
b^P
a^P
g^P
k^P
f^P
e^P
VH_1

NOTE.—As a general rule, it is well to assume the station point on a vertical line half way between two lines dropped from the extreme edges of the diagram, as indicated. This is not necessary, but, as will be explained later, it usually insures a more pleasing perspective projection.

Next find the vanishing points for the different systems of lines in the object (§ 12). There are three systems of lines in the block, formed by its three sets of parallel edges.

1st. A system formed by the four horizontal edges vanishing to the right: *ab*, *ef*, *dc*, and *kg*.

2d. A system formed by the four horizontal edges vanishing towards the left: *ad*, *ek*, *bc*, and *fg*.

3d. A system formed by the four vertical edges.

First find the vanishing point for the system parallel to *ab* by drawing through the station point a line parallel to *ab* and finding where it pierces the picture plane (24 *g*). A^H drawn through SP^H is the horizontal projection of such a line. Its vertical projection (A^V), drawn through SP^V, will coincide with VH, and its vanishing point will be found on VH at v^{ab} (§ 51). All lines in the perspective of the object that are parallel to *ab* will meet at v^{ab} (§ 24 *a*). In a similar manner find v^{ad}, which will be the vanishing point for all lines parallel to *ad*.

54. If the method for finding any vanishing point is applied to the system of vertical lines, it will be found that this vanishing point will lie vertically over SP^V at infinity. That is to say, since all vertical lines are parallel to the picture plane, if a vertical line is drawn through the station point, it will never pierce the picture plane. Therefore (24 *g*), the perspective of the vanishing point of a vertical line cannot be found within any finite limits, but will be *vertically over* SP^V*, and at an infinite distance from it.* In a perspective projection *all vertical lines are drawn actually vertical, and not converging towards one another.*

NOTE.—This is true of all lines in an object which are *parallel to the picture plane.* Thus, *the perspective of any line which is parallel to the picture plane, will actually be parallel to the line itself;* and *the perspectives of the elements of a system of lines parallel to the picture plane, will be drawn parallel to, and not converging towards, one another.* That this must be so, is evident, since, if the perspectives of such a system of lines did converge towards one another, they would meet within finite limits. But it has just been found that the perspective of the vanishing point of such a system is at infinity. The perspectives of the elements of any system can meet only at the perspective of their vanishing point, and must, therefore, in a system parallel to the picture plane, be drawn parallel to one another.

The directions of the perspectives of all lines in the object have now been determined, and will be as follows:

All lines parallel to ab will meet at v^{ab}.
All lines parallel to ad will meet at v^{ad}.
All vertical lines will be drawn vertical.

Since the point e is in the base of the object, it lies on the plane of the ground, and also, since the line ae lies in the picture plane, the point e must lie on the intersection of the plane of the ground with the picture plane. Therefore, the point e must lie in VH_1, and must be vertically under the point e in the diagram. Since the point e lies in the picture plane, it will be its own perspective; and e^p will be found on VH_1, vertically under e in the diagram, as shown in the figure. · From e^p the perspective of the lower edges of the cube will vanish at v^{ab} and v^{ad}, respectively, as indicated.

f^p is the perspective of the point f, and will be found on the lower edge of the block, vertically under the intersection of HPP with the horizontal projection of the visual ray drawn through the point f in the diagram.

Similarly, k^p is found on the lower edge of the block, vertically under the intersection of HPP and the visual ray drawn through the point k in the diagram.

Vertical lines drawn through f^p, e^p, and k^p, will represent the perspectives of the visible vertical edges of the block.

The edge e^pa^p being in the picture plane will be its own perspective, and show in its true size (§ 24 h). Therefore, a^p may be established by making the distance e^pa^p equal to e^Va^V as taken from the given elevation. From a^p two of the upper horizontal edges of the block will vanish at v^{ab} and v^{ad}, respectively, establishing the points b^p and d^p, by their intersections with the vertical edges drawn through k^p and f^p, respectively. Lines drawn through

d^p and b^p, and vanishing respectively at v^{ab} and v^{ad}, will intersect at c^p, and complete the perspective of the block.

Before going farther in the notes, the student should solve the problems on Plate I.

LINES OF MEASURES.

55. Any line which lies in the picture plane will be its own perspective, and show the true length of the line (24 *h*). Such a line is called a **Line of Measures.**

In the last problem, the line *ae*, being in the picture plane, was a line of measures; that is to say, its length could be laid off directly from the given data, and from this length the lengths of the remaining lines in the perspective drawing could be established. Fig. 20 shows a similar problem. The line *ae* lies in the picture plane, and a^pe^p is, therefore, a line of measures for the object.

56. Besides this principal line of measures, other lines of measures may easily be established by extending any vertical plane in the object until it intersects the picture plane. This intersection, since it lies in the picture plane, will show in its true size, and will be an **auxiliary line of measures.** All points in it will show at their true height above the plane of the ground. Thus, in Fig. 20, a^pe^p is the principal line of measures, and shows the true height of the block. If the rear vertical faces of the block are extended till they intersect the picture plane, these intersections (m^pn^p and o^pp^p) will be auxiliary lines of measures, and will also show the true height of the block. It will be noticed in the figure that m^pn^p and o^pp^p are each equal to a^pe^p. Either one of these lines could have been used to determine the vertical height of the perspective of the block. For illustration, suppose it is desired to find the height of the perspective, using the line o^pp^p as the line of measures. Assume the vanishing points (v^{ad} and v^{ab}) for the two systems of horizontal edges in the block to have been established as in the previous case. Now extend the line *bc* (in the diagram), which represents the horizontal projection of the face *cbf*, till it intersects HPP. From this intersection drop a vertical line *op* which will represent the intersection of the vertical face *cbf* with the picture plane, and will be a line of measures for the face. p^p, where this line of measures intersects VH_1, will be the

point where the lower horizontal edge (produced) of the face cbf intersects the picture plane. Measure off the distance p^Po^P equal to the true height of the block, as given by the elevation. Two lines drawn through o^P and p^P respectively, and vanishing at v^{ad}, will represent the perspectives of the upper and lower edges of the face cbf, produced. The perspective (b^P), of the point b, will be found on the perspective of the upper edge of the face cbf, vertically below the intersection of HPP with the horizontal projection of a visual ray drawn through the point b in the diagram. A vertical line through b^P will intersect the lower horizontal edge of the face cbf in the point f^P. Lines drawn respectively through b^P and f^P, vanishing at v^{ab}, will establish the perspectives of the upper and lower horizontal edges of the face $abfe$ The points a^P and e^P will be found vertically under the points a and e in the diagram. The remainder of the perspective projection may now easily be determined.

57. The perspectives of any points on the faces of the block may be found by means of the diagram and one of the lines of measures.

Let the points g^V, h^V, k^V, and l^V, in the given elevation, determine a square on the face $abfe$ of the block. Let the points g, h, k, and l, represent the position of the square in the diagram. Extend the upper and lower horizontal edges of the square, as shown in elevation, until they intersect the vertical edge a^Ve^V in the points t^V and v^V. To determine the perspective of the square, lay off on a^Pe^P, which is a line of measures for the face $abfe$, the divisions t^P and v^P taken directly from the elevation. Two lines drawn through t^P and v^P respectively, vanishing at v^{ab}, will represent the perspectives of the upper and lower edges (produced) of the square. g^P will be found on the perspective of the upper edge, vertically under the intersection of HPP with the horizontal projection of a visual ray drawn through the point g in the diagram. The position of k^P may be established in a similar manner. Vertical lines drawn through g^P and k^P respectively, will complete the perspective of the square.

58. The auxiliary line of measures o^Pp^P might have been used instead of a^Pe^P. In this case, o^Pp^P should be divided by the points w^P and y^P, in the same way that ae, in elevation, is divided

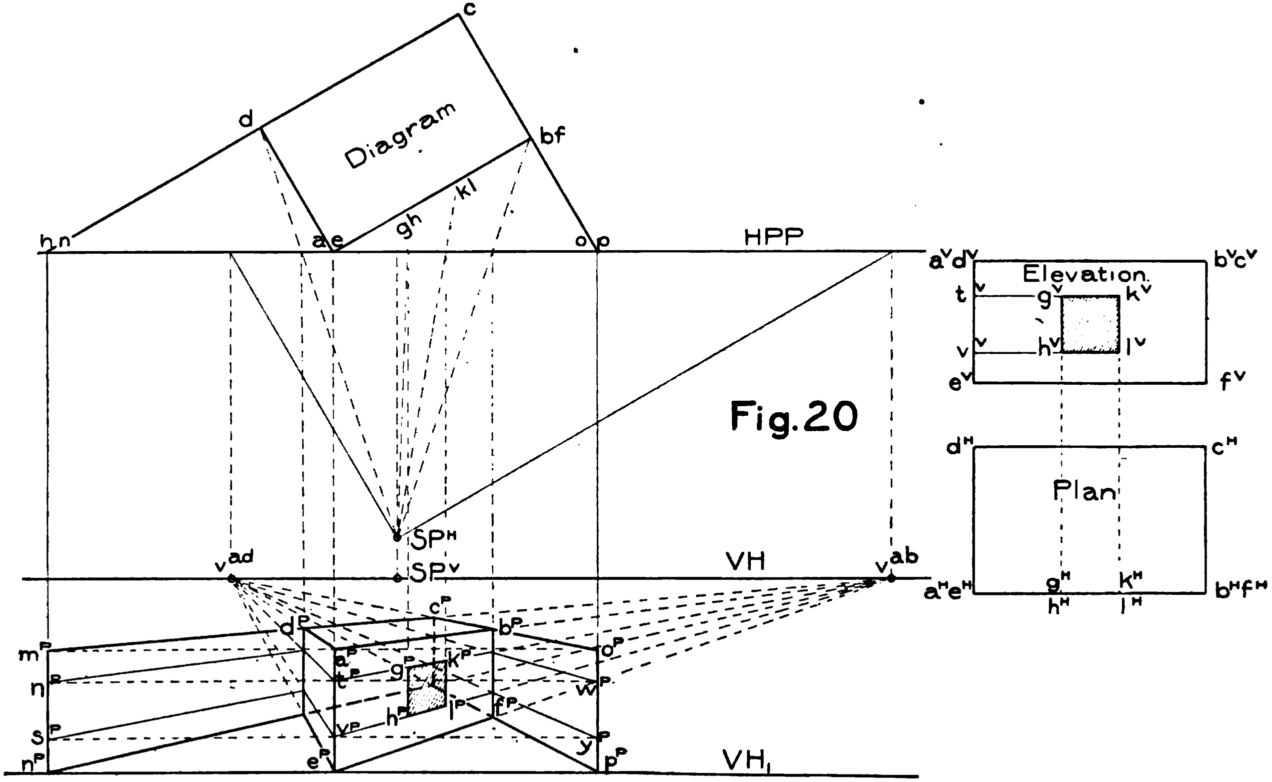


Fig.20

Diagram
c
d
bf
kl
gh
hn
ae
op
HPP
$a^v d^v$
$b^v c^v$
Elevation.
t^v
g^v
k^v
v^v
h^v
l^v
e^v
f^v
d^H
c^H
Plan
$a^H e^H$
g^H
h^H
k^H
l^H
$b^H f^H$
SP^H
SP^v
v^{ad}
VH
v^{ab}
m^P
n^P
s^P
n^P
d^P
c^P
b^P
a^P
t^P
g^P
k^P
o^P
w^P
h^P
l^P
f^P
v^P
y^P
e^P
p^P
VH_1

by the points *t* and *v*. Through w^P and y^P, draw horizontal lines lying in the plane *cbf*, for which o^Pp^P is a line of measures. These lines will vanish at v^{ad}, and intersect the vertical edge b^Pf^P of the block. From these intersections draw horizontal lines lying in the plane *abef*, vanishing at v^{ab}, and representing the upper and lower edges of the square. The remainder of the square may be determined as in the previous case.

In a similar manner, the auxiliary line of measures m^Pn^P might have been used to determine the upper and lower edges of the square. This construction has been indicated, and the student should follow it through.

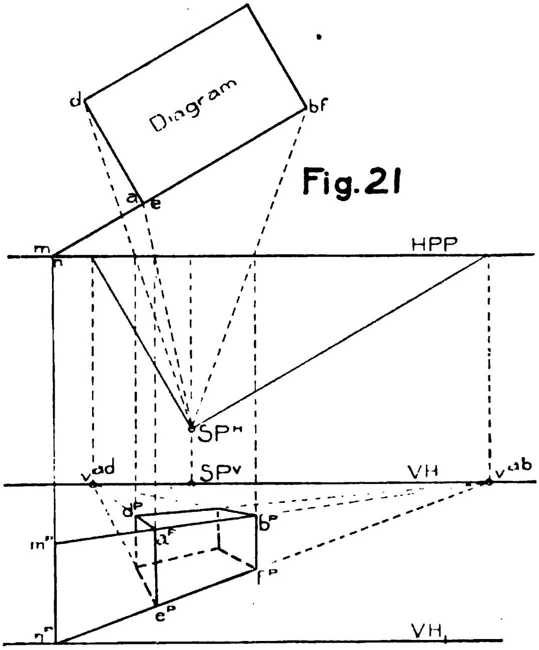


Fig. 21

59. It sometimes happens that no line in the object lies in the picture plane. In such a case there is no principal line of measures, and some vertical plane in the object must be extended until it intersects the picture plane, forming by this intersection an auxiliary line of measures. Fig. 21 illustrates such a case. A rectangular block, similar to those shown in Figs. 19 and 20, is

situated some distance behind the picture plane, as indicated by the relative positions of HPP and the diagram.

Its perspective projection will evidently be smaller than if the vertical edge *ae* were in the picture plane, as was the case in Figs. 19 and 20, and the perspective of *ae* will evidently be shorter than the true length of *ae*. There is, therefore, no line in the object that can be used for a line of measures. It becomes necessary to extend one of the vertical faces of the block until it intersects the picture plane, and shows by the intersection its true vertical height. Thus, the plane *abfe* has been extended, as indicated in the diagram, until it intersects the picture plane in the line *mn*. This intersection is an auxiliary line of measures for the plane *abfe*, and $m^P n^P$ shows the true vertical height of this plane.

Either of the other vertical faces of the block, as well as the face *abfe*, might have been extended until it intersected the picture plane, and formed by this intersection a line of measures for the block.

The vanishing points for the various systems of lines have been found as in the previous cases.

From m^P and n^P, the horizontal edges of the face *abfe* vanish to v^{ab}. a^P will be found on the upper edge of this face, vertically below the intersection of HPP with the horizontal projection of the visual ray through the point *a* in the diagram. A vertical line through a^P will represent the perspective of the nearest vertical edge of the block, and will establish the position of e^P.

In a similar manner, b^P will be found vertically below the intersection of HPP with the horizontal projection of the visual ray through the point *b* in the diagram. A vertical line through b^P will establish f^P, and complete the perspective of the face *abfe*. Having found the perspective of this face, the remainder of the block may be determined as in the previous problems.

NOTE. — Instead of being some distance behind the picture plane, the block might have been wholly or partly in front of the picture plane. In any case, find the intersection with the picture plane of some vertical face of the block (produced, if necessary). This intersection will show the true vertical height of the block.

At this point the student should solve Plate II.

60. PROBLEM V. Fig. 22. **To find the perspective of a house, the projections of which are given.**

The plan, front, and side elevations of the house are shown in the figure. The side elevation corresponds to the projection on the profile plan, used in the study of projections. This problem is a further illustration of the method of revolved plan and of the use of horizontal vanishing points and auxiliary lines of measures. It is very similar to the three previous problems on the rectangular blocks.

The first step in the construction of the perspective projection is to make a diagram (§ 53) which shall show the horizontal projections of all the features that are to appear in the drawing. The diagram should be placed at the top of the sheet, and turned so that the sides of the house make the desired angles with the picture plane. In Fig. 22 the diagram is shown with the long side making an angle of 30° with the picture plane. The roof lines, the chimney, and the positions of all windows, doors, etc., that are to be visible in the perspective projection, will be seen marked on the diagram.

The nearest vertical edge of the house is to lie in the picture plane. This is indicated by drawing HPP through the corner of the diagram which represents this nearest edge.

VH may be chosen at any convenient distance below HPP.

The position of the station point is shown in the figure by its two projections SP^V and SP^H. SP^V must always be in VH. The distance between SP^H and HPP shows the distance of the observer's eye in front of the picture plane (§ 43).

v^{ab} and v^{ad} may be found as in the preceding problems.

The position of the plane on which the object is to rest should next be established by drawing VH_1, the distance between VH and VH_1 showing the height of the observer's eye above the ground (§ 44).

In addition to the plane of the ground represented by VH_1, a second ground plane, represented by VH_2, has been chosen some distance below VH_1. In the figure, two perspective projections have been found, one resting on each of these two ground planes. The perspective which rests upon the plane represented by VH_1 shows the house as though seen by a man standing with his eyes nearly on a level with the tops of the windows (§ 29). The view which rests on the plane represented by VH_2 shows a bird's-eye view of the house, in which the eye of the observer (always in VH) is at a distance above the plane on which the view rests, equal to about two and one-half times the height of the ridge of the house above the ground.

These two perspective projections illustrate the effect of changing the distance between VH and the vertical trace (§ 34, note) of the plane on which the perspective projection is supposed to rest. The construction of both views is exactly the same. The following explanation applies to both equally well, and the student may consider either in studying the problem.

61. We will first neglect the roof of the house, and of the porch. The remaining portion of the house will be seen to consist of two rectangular blocks, one representing the main body of the house, and the other representing the porch.

The block representing the main part of the house occupies a position exactly similar to that of the block shown in Fig. 19. First consider this block irrespective of the remainder of the house. A vertical line dropped from the corner of the diagram that lies in HPP will be a measure line for the block, and will establish, by its intersection with VH_1 (or VH_2), the position of the point e^P, in exactly the same way that the point e^P in Fig. 19 was established. e^Pa^P shows the true height of the part of the house under consideration, and should be made equal to the corresponding height a^Ve^V, as shown by the elevations. The rectangular block representing the main part of the house may now be drawn exactly as was the block in Fig. 19, Problem IV.

62. Having found the perspective of the main part of the house, the porch (without its roof) may be considered as a second rectangular block, no vertical edge of which lies in the picture plane. It may be treated in a manner exactly similar to that of the block shown in Fig. 21, § 59. We may consider that the *rear* vertical face of the block, which forms the porch of the house (g, q), has been extended until it intersects the picture plane in the line ae, giving a line of measures for this face, just as in Fig. 21 the *nearest* vertical face of the block was extended until it intersected the picture plane in the line of measures mn.

On e^pa^p, make e^pc^p equal to the true height of the vertical wall of the porch, as given by the elevation. A line through c^p, vanishing at v^{ab}, will be the perspective of the upper horizontal edge of the rear face of the block which forms the porch. The line through e^p, vanishing at v^{ab}, which forms the lower edge of the front face of the main body of the house, also forms the lower edge of the rear face of the porch. Through the point *h* in the diagram, draw a visual ray, and through the intersection of this visual ray with HPP drop a vertical line. Where this vertical line crosses the upper and lower horizontal edges of the rear face of the porch, will establish the points g^p and h^p respectively. Having found the vertical edge g^ph^p, the remainder of the perspective of the porch (except the roof) can be found without difficulty, the horizontal edges of the porch vanishing at either v^{ab} or v^{ad}, according to the system to which they belong. Each vertical edge of the porch will be vertically below the point where HPP is crossed by a visual ray drawn through the point in the diagram which represents that edge. The fact that the porch projects, in part, in front of the picture plane, as indicated by the relation between the positions of the diagram and HPP, makes absolutely no difference in the construction of the perspective projection.

All of the vertical construction lines have not been shown in the figure, as this would have made the drawing too confusing. The student should be sure that he understands how every point in the perspective projection has been obtained, and, if necessary, should complete the vertical construction lines with pencil.

63. Having found the perspective of the vertical walls of the main body of the house, and of the porch, the next step will be to consider the roof of the main part of the house.

Imagine the horizontal line *tw*, which forms the ridge of the roof, to be extended until it intersects the picture plane. This is shown on the diagram by the extension of the line *tw* until it intersects HPP. From this intersection drop a vertical line, as indicated in the figure. This vertical line may be considered to be the line of measures for an imaginary vertical plane passing through the ridge of the house, as indicated by the dotted lines in the plan and elevations of the house. On this line of measures; lay off the distance *nm* measured from VH_1 (or VH_2), equal to the true height of the ridge above the ground as given by the elevations of the house. A line drawn from the point *m*, vanishing at v^{ab}, will represent the ridge of the house, indefinitely extended. From the points *t* and *w* in the diagram draw visual rays. From the intersections of these visual rays with HPP drop vertical lines which will establish the positions of t^P and w^P on the perspective of the ridge of the roof. Lines drawn from t^P and w^P to the corners of the vertical walls of the house, as indicated, will complete the perspective of the roof.

To find the perspective of the porch roof, draw a visual ray through the point *y* on the diagram, and from its intersection with HPP drop a vertical. Where this vertical crosses the line a^Pb^P will give y^P, one point in the perspective of the ridge of the porch. The perspective of the ridge will be represented by a line through y^P, vanishing at v^{ad}. The point z^P in the ridge will be vertically below the intersection of HPP with the visual ray drawn through the point *z* on the diagram. Lines drawn from y^P and z^P to the corners of the vertical walls of the porch, as indicated, will complete the perspective of the porch roof.

64. The perspective of the chimney must now be found. It will be seen that the chimney is formed by a rectangular block; and if it is supposed to extend down through the house, and rest upon the ground, it will be a block under exactly the same conditions as the one shown in Fig. 21, § 59. In order to find its perspective, extend its front vertical face, as indicated on the diagram, till it intersects HPP. A vertical line dropped from this intersection will be a line of measures for the front face of the chimney, and the distance *ps*, laid off on this line from VH_1 (or VH_2), will show the true height of the top of the chimney above the ground, as given on the elevation. The distance *so*, measured from the point *s* on the line of measures, will be the true vertical height of the face of the chimney that is visible above the roof. Lines through *s* and *o*, vanishing at v^{ab}, will represent the horizontal edges of the front visible face of the chimney. The vertical edges of this face will be found vertically below the points where HPP is crossed by the visual rays drawn through the horizontal projections of these edges on the diagram.

Having determined the perspective of the front face of the chimney, the perspectives of the remaining edges may be found as in the cases of the rectangular blocks already discussed. From the point r in the diagram, where the ridge of the roof intersects the left hand vertical face of the chimney, draw a visual ray intersecting HPP, and from this intersection drop a vertical line to the perspective of the ridge of the house, giving the perspective (r^P) of the point where the ridge intersects the left hand face of the chimney. A line drawn from r^P to the nearest lower corner of the front face of the chimney will be the perspective of the intersection of the plane of the roof with the left hand face of the chimney.

65. The problem of finding the perspectives of the windows and door is exactly similar to that of finding the perspective of the square *hgkl* on the surface of the block shown in Fig. 20.

It will be noticed that the intersection with the picture plane of the left hand vertical face of the porch gives a line of measures (§ 55 and § 59, note) for this face. This line may be used conveniently in establishing the height of the window in the porch.

At this point in the course the student should solve Plate III.

VANISHING POINTS OF OBLIQUE LINES.

66. The perspective of the house in the last problem was completely drawn, using only the vanishing points for the two principal systems of horizontal lines. By this method it is possible to find the perspective projection of any object. But it is often advisable, for the sake of greater accuracy, to determine the vanishing points for systems of oblique lines in the object, in addition to the vanishing points for the horizontal systems.

Take, for example, the lines $g^P y^P$ and $x^P z^P$ in Fig. 22. The perspective projections of these two lines were obtained by first finding the points g^P, y^P, x^P, and z^P, and then connecting g^P with y^P, and x^P with z^P. As the distances between g and y, and x and z, are very short, a slight inaccuracy in determining the positions of their perspectives might result in a very appreciable inaccuracy in the directions of the two lines $g^P y^P$ and $x^P z^P$. These two lines belong to the same system, and should approach one another as they recede. Unless the points which determine them are found with great care, the two lines may approach too rapidly, or even diverge, as they recede from the eye. In the latter case, the drawing would be absolutely wrong in principle, and the result would be very disagreeable to the trained eye. If, however, the perspective of the vanishing point of the system to which these two lines belong, can be found, and the two lines be drawn to meet at this vanishing point, the result will necessarily be accurate.

The line through r^P, which forms the intersection between the roof of the house and the left hand face of the chimney, is a still more difficult one to determine accurately. Its length is so short that it is almost impossible to establish its exact direction from the perspective projections of its extremities. If the perspective of its vanishing point can be found, however, its direction at once becomes definitely determined.

67. It is not a difficult matter to find the perspective of the vanishing point for each system of lines in an object. The method is illustrated in Fig. 23. The general method for finding the perspective of the vanishing point for any system of lines has already been stated in § 24 *g*, and illustrated in Figs. 16, 17, and 18, §§ 50, 51, and 52. It remains only to adapt the general method to a particular problem, such as that shown in Fig. 23.

The plan and elevation of a house are given at the left of the figure. The diagram has been drawn at the top of the sheet, turned at the desired angle. The assumed position of the station point is indicated by its two projections, SP^V and SP^H. VH necessarily passes through SP^V.

68. In order to find the perspective of the vanishing point of any system of lines, the vertical and horizontal projections of some element of the system must be known (see method of Problem III.). The diagram gives the horizontal projection of every line in the object which is to appear in the perspective projection. The diagram, however, has been turned through a certain horizontal angle in order to show the desired perspective view, and there is no revolved elevation to agree with the revolved position of the diagram. A revolved elevation could, of course, be con-

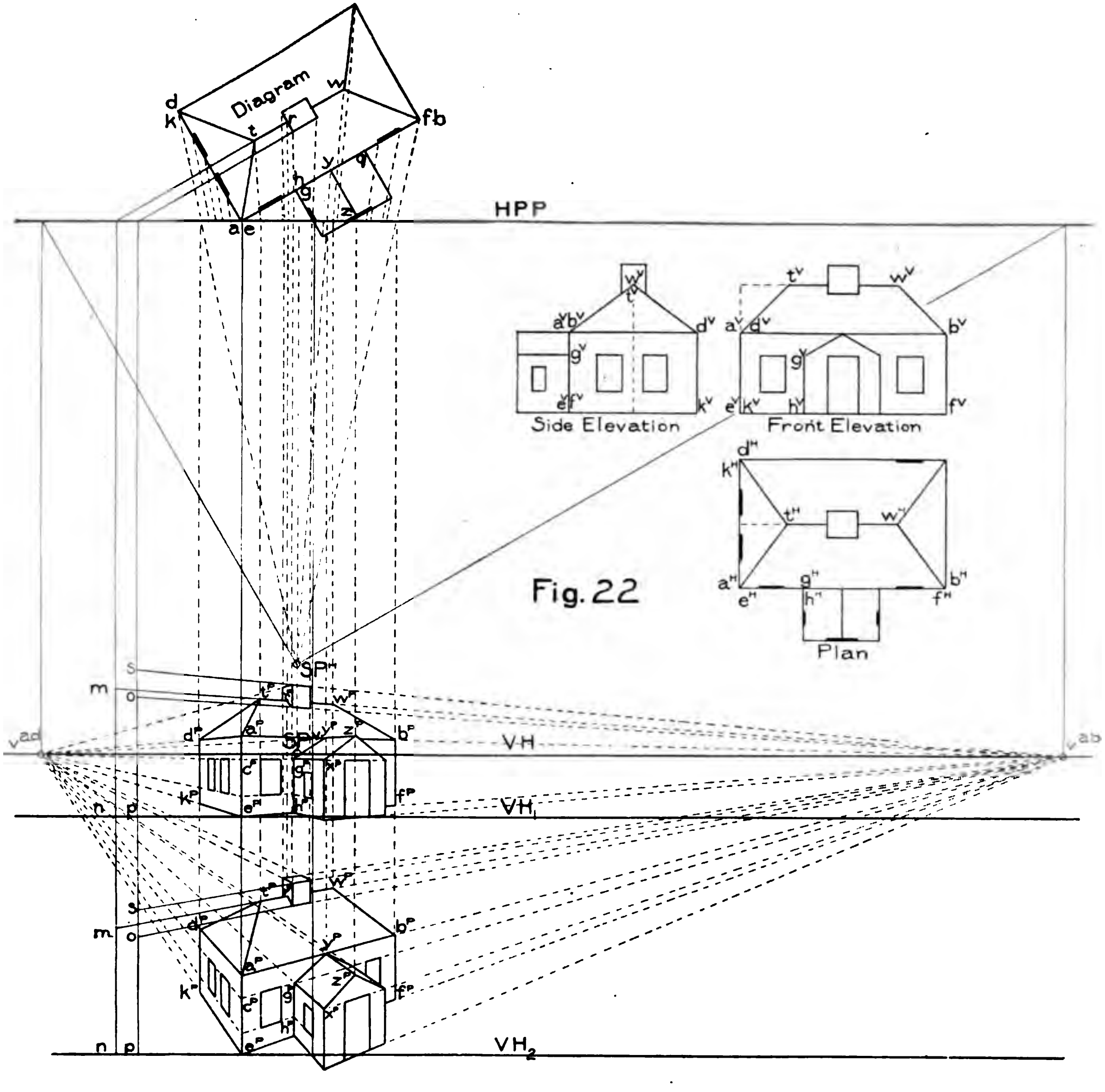
Diagram
d
k
t
r
w
fb
h
y
g
z
a e
HPP
Side Elevation
Front Elevation
Plan
$a^V b^V$
d^V
g^V
$e^V f^V$
k^V
t^V
w^V
a^V
e^V
h^V
b^V
f^V
d^H
k^H
t^H
w^H
a^H
e^H
g^H
h^H
b^H
f^H
SP^H
s
m
o
n
p
V_{ad}
V_{ab}
VH
VH_1
VH_2
t^P
w^P
d^P
a^P
b^P
c^P
e^P
k^P
f^P
g^P
h^P
x^P
y^P
z^P

Fig. 22

structed by revolving the given plan of the object until all its lines were parallel to the corresponding lines in the diagram, and then finding the revolved elevation of the object corresponding to the revolved position of the plan.

NOTE. — The method of constructing a revolved elevation has been explained in detail in the Instruction Paper on Mechanical Drawing, Part III., Page 12.

Having constructed the revolved plan and elevation of the object to agree with the position of the diagram, we should then have the vertical and horizontal projections of a line parallel to each line that is to appear in the perspective drawing, and the method of Problem III. could be applied directly.

This is exactly the process that will be followed in finding the vanishing points for the oblique lines in the object, except that instead of making a complete revolved plan and elevation of the house, each system of lines will be considered by itself, and the revolved plan and elevation of each line will be found as it is needed, without regard to the remaining lines in the object.

69. All the lines in the house belong to one of eleven different systems that may be described as follows: —

A vertical system, to which all the vertical lines in the house belong. The perspective of the vanishing point of this system cannot be found within finite limits (§ 54).

Two horizontal systems parallel respectively to *ab* and *ad* (see diagram). The perspectives of the vanishing points of these systems will be found in VH (§ 24 *c*, note).

Five systems of lines vanishing upward, parallel respectively to *af*, *bg*, *mn*, *on*, and *hk* (see diagram). The perspectives of the vanishing points of these systems will be found to lie above VH (§ 51, note).

Three systems of lines vanishing downward, parallel respectively to *fd*, *gc*, and *kl* (see diagram). The perspectives of the vanishing points of these systems will be found below VH (§ 51, note).

NOTE. — To determine whether a line vanishes upward or downward, proceed as follows: —

Examine the direction of the line as shown in the *diagram*. Determine which end of the line is the farther behind the picture plane. If the *more distant* end of the line is *above* the nearer end, the line vanishes *upward*, and the perspective of its vanishing point will be found above VH.

If, on the other hand, the *more distant* end of the line is *lower* than the nearer end, the line vanishes *downward*, and the perspective of its vanishing point will be found below VH.

For illustration, consider the line *bg*. The diagram shows the point *g* to be farther behind the picture plane than the point *b*, while the given elevation shows the point *g* to be higher than the point *b*. Therefore the line *rises* as it *recedes*, or, in other words, it *vanishes upward*.

In the case of the line *fd*, the diagram shows the point *d* to be farther behind the picture plane than the point *f*, while the elevation shows the point *d* to be lower than the point *f*. Therefore the line must vanish downward, and its vanishing point be found below VH.

If the horizontal projection of a line, as shown by the diagram, is parallel to HPP, the line itself is parallel to the picture plane, and the perspective of its vanishing point cannot be found within finite limits (§ 54, note). *The perspective projections of such a* *system of lines will show the true angle which the elements of the system make with the horizontal coordinate.*

70. The construction for the vanishing points in Fig. 23 is shown by dot and dash lines.

The vanishing points for the two systems of horizontal lines have been found at v^{ab} and v^{ad} respectively, as in the preceding problems.

Next consider the line *af*. The first step is to construct a revolved plan and elevation of this line to agree with the position of the diagram. Revolve the horizontal projection ($a^H f^H$) of the line in the given plan about the point f^H, until it is parallel to the line *af* in the diagram. During this revolution, the point f^H remains stationary, while the point a^H describes a horizontal arc, until $a^H f^H$ has revolved into the position shown by the red line $a_1^H f^H$, which is parallel to the line *af* in the diagram. The vertical projection $a^V f^V$ must, of course, revolve with the horizontal projection. The point f^V remains stationary, while the horizontal arc described by the point *a* shows in vertical projection as a horizontal line. At every point of the revolution the vertical projection of the point *a* must be vertically in line with its horizontal projection. When a^H has reached the position a_1^H, a^V will be vertically above a_1^H at the point a_1^V, and $a_1^V f^V$ will be the revolved elevation of the line.

We now have the vertical and horizontal projections ($a_1^V f^V$ and $a_1^H f^H$) of an element of the system to which the roof line, represented in the diagram by *af*, belongs. The vanishing point of this system may be determined as in Problem III. Draw through SP^H a line parallel to $a_1^H f^H$ (or *af* in the diagram), representing the horizontal projection of the visual element of the system. Draw through SP^V a line parallel to $a_1^V f^V$, representing the vertical projection of the visual element of the system. The visual element, represented by the two projections just drawn, pierces the picture plane at v^{af} (§ 45, note), giving the perspective of the vanishing point for the roof line, represented by *af* in the diagram.

In a similar manner the vanishing point for the roof line, represented in the diagram by *bg*, may be determined. First find, from the given plan and elevation of the object, a revolved plan and elevation of bg, to agree with the position of the line in the diagram. Revolve $b^H g^H$ in the given plan about the point g^H, until it is parallel to bg in the diagram, and occupies the position indicated by the line $b_1^H g^H$. The corresponding revolved elevation is represented by the red line $b_1^V g^V$.

$b_1^H g^H$ and $b_1^V g^V$ now represent respectively the horizontal and vertical projections of an element of the system to which the roof line, represented by bg in the diagram, belongs. The vanishing point of this system can be found by Problem III. Through SP^H draw a line parallel to $b_1^H g^H$ (or bg in the diagram), representing the horizontal projection of the visual element of the system; and through SP^V draw a line parallel to $b_1^V g^V$, representing the vertical projection of their visual element. The visual element, represented by these two projections, pierces the picture plane at v^{bg}, giving the perspective of the vanishing point of the roof line, represented in the diagram by the line bg.

By a similar process, $h^H k_1^H$ and $h^V k_1^V$ are found to represent respectively the horizontal and vertical projections of an element of the system to which belongs the roof line represented in the diagram by the line hk. The perspective of the vanishing point of this line has been found at v^{hk}.

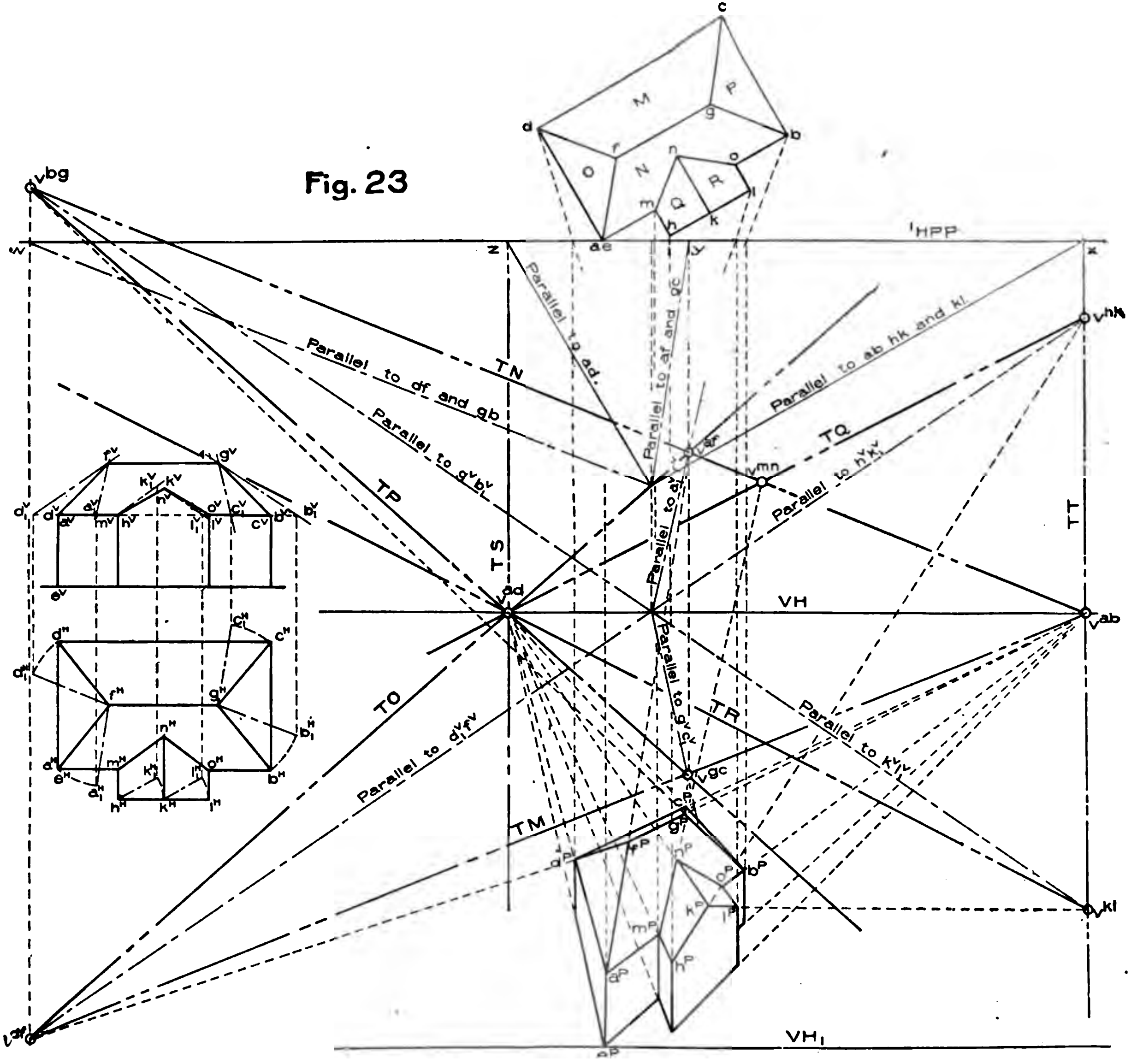
v^{af}, v^{bg}, and v^{hk} have all been found to lie above VH (§ 51. note).

71. v^{fd}, v^{gc}, and v^{kl} are found exactly as were v^{af}, v^{bg}, and v^{hk}; but, as the systems to which they belong vanish downward, they will lie below VH (§ 51, note).

Thus, $f^H d_1^H$ and $f^V d_1^V$ are respectively the horizontal and vertical projections of an element of the system represented by fd in the diagram. A line drawn through SP^H, parallel to $f^H d_1^H$ (or fd in the diagram), will intersect HPP in the point w. A vertical line through w will intersect a line through SP^V parallel to $f^V d_1^V$, below VH.

72. Having found the perspectives of these vanishing points, the perspectives of the vanishing traces of all the planes in the object should be drawn as a test of the accuracy with which the vanishing points have been constructed. The roof planes in the house are lettered with the capital letters M, N, O, P, etc., on the diagram.

Fig. 23


HPP
VH
VH₁
TT
TS
TN
TP
TO
TQ
TR
TM
Parallel to ad.
Parallel to af and gc
Parallel to ab hk and kl.
Parallel to df and gb
Parallel to g^v b^v
Parallel to h^v k^v
Parallel to d^v f^v
Parallel to g^v c^v
Parallel to k^v l^v
V bg
V hk
V ab
V kl
V ad
V mn
V gc
V af
M
N
O
P
Q
R
x
y
z
w

The plane O contains the lines *af*, *ad*, and *fd*. Therefore, the vanishing trace (TO) of the plane must be a straight line passing through the three vanishing points, v^{af}, v^{ad}, and v^{fd} (§ 24 *d*). If all three of these vanishing points do not lie in a straight line, it shows some inaccuracy, either in draughting or in the method used in finding some of the vanishing points. The student should not be content until the accuracy of his work is proved by drawing the vanishing trace of each plane in the object through the vanishing points of all lines that lie in that plane.

The plane M contains the lines *fd*, *gc*, and *dc*. The last line belongs to the system *ab*, and hence its vanishing point is v^{ab}. The vanishing trace (TM) of the plane M must pass through v^{fd}, v^{gc}, and v^{ab}.

Similarly, the vanishing trace (TP) of the plane P must pass through v^{gc}, v^{bg}, and v^{ad}. TN must pass through v^{ab}, v^{af}, and v^{bg}. TQ must pass through v^{hk} and v^{ad}. TR must pass through v^{kl} and v^{ad}.

73. The vanishing trace of a vertical plane will always be a *vertical line* passing through the vanishing points of all lines which lie in the plane. Therefore, the vanishing trace of the vertical planes in the house that vanish towards the left will be represented by a vertical line (TS) passing through v^{ad}.

The vanishing trace of the vertical planes of the house that vanish towards the right will be represented by a vertical line (TT) passing through v^{ab}. As the vertical plane which forms the face of the porch belongs to this system, and as this plane also contains the lines *hk* and *kl*, TT will be found to pass through v^{hk} and v^{kl} as well as v^{ab}.

74. It will be noticed that the vanishing points for the lines *mn* and *on* have not been found. These vanishing points might have been found in a manner exactly similar to that in which the other vanishing points were found, or they may be determined now, directly from the vanishing traces already drawn, in the following manner: —

The line *mn* is seen to be the line of intersection of the two planes N and Q. Therefore (§ 24 *e*) v^{mn} must lie at the intersection of TN and TQ.

For a similar reason, v^{on} must lie at the intersection of TN and TR. TN and TR do not intersect within the limits of the plate, but they are seen to converge as they pass to the left, and, if produced in that direction, would meet at the vanishing point for the line *on*.

75. Having found v^{ab}, v^{ad}, v^{bg}, and v^{fd}, TN could have been drawn through v^{ab} and v^{bg}; and TO could have been drawn through v^{ad} and v^{fd}. As *af* is the intersection of the two planes N and O, v^{af} could have been found at the intersection of TN and TO without actually constructing this vanishing point.

Similarly, v^{gc} could have been determined by the intersection of TM and TP.

By an examination of the plate, the student will notice that the vanishing point for each line in the object is formed at the intersection of the vanishing traces of the two planes of which the line forms the intersection. Thus, the line *ad* forms the intersection between the plane O and the left hand vertical face of the house. v^{ad} is found at the intersection of TO and TS.

The line *fg*, which forms the ridge of the roof, is the intersection of the planes M and N. The vanishing point for *fg* is v^{ab}, and TM and TN will be found to intersect at v^{ab}. v^{hk} is found at the intersection of TQ and TT, v^{kl} is found at the intersection of TR and TT, etc.

It will be noticed also that the two lines *hk* and *kl* lie in the same vertical plane, and make the same angle with the horizontal, one vanishing upward, and one vanishing downward. Since both lines lie in the same vertical plane, both of their vanishing points will be found in the vertical line which represents the vanishing trace of that plane. Also, since both lines make equal angles with the horizontal, the vanishing point of the line vanishing upward will be found as far above VH as the vanishing point of the line vanishing downward is below VH.

In a similar way, the line *bg* vanishes upward, and the line *fd* vanishes downward; each making the same angle with the horizontal (as shown by the given plan and elevation). These two lines do not lie in the same plane, but may be said to lie in two imaginary vertical planes which are parallel to one another. Their vanishing points will be seen to lie in the same vertical line, v^{bg} being as far above VH as v^{fd} is below it.

As a general statement, it may be said that if two lines lie in the same or parallel vertical planes, and make equal angles with the horizontal, one vanishing upward and the other vanishing downward, the vanishing points for both lines will be found vertically in line with one another, one as far above VH as the other is below it.

This principle is often of use in constructing the vanishing point diagram. Thus, having found v^{hk}, v^{kl} could have been determined immediately by making it lie in a vertical line with v^{hk}, and as far below VH as v^{hk} is above it.

VANISHING POINT DIAGRAM.

76. The somewhat symmetrical figure formed by the vanishing traces of all the planes in the object, together with all vanishing points, HPP, and the vertical and horizontal projections of the station point, is called the *Vanishing Point Diagram* of the object.

77. Having found the complete vanishing point diagram of the house, the perspective projection may be drawn. VH_1 may be chosen in accordance with the kind of a perspective projection it is desired to produce (§ 29). In order that all the roof lines may be visible, VH_1 has been chosen far below VH. The resulting perspective is a somewhat exaggerated bird's-eye view.

The point e^P will be found on VH_1, vertically under the point e in the diagram. a^Pe^P lies in the picture plane, and shows the true height of the vertical wall of the house. From a^P and e^P, the horizontal edges of the walls of the main house vanish to v^{ab} and v^{ad}.

The points d^P, b^P, m^P, and o^P are found on the upper horizontal edges of the main walls, vertically under the points where HPP is crossed by visual rays drawn through the points d, b, m, and o in the diagram. Vertical lines from d^P and b^P complete the visible vertical edges of the main house.

In a similar manner the perspective of the vertical walls of the porch is obtained.

Each roof line vanishes to its respective vanishing point. a^Pf^P vanishes at v^{af}. f^Pd^P vanishes at v^{fd}. These two lines intersect in the point f^p. The ridge of the main house passes through f^p, vanishing at v^{ab}. g^pc^p vanishes at v^{gc}, passing through the point c^p, which has already been determined by the intersection of the two upper rear horizontal edges of the main walls. b^pg^p vanishes at v^{bg}, completing the perspective of the main roof.

In the porch, h^pk^p vanishes at v^{hk}, passing through the point h^p, already determined by the vertical walls of the porch. k^pl^p passes through l^p, and vanishes at v^{kl}. From k^p the ridge of the porch roof vanishes at v^{ad}. From m^p, a line vanishing at v^{mn} will intersect the ridge in the point n^p, and represent the intersection of the roof planes Q and N. The vanishing point for o^pn^p falls outside the limits of the plate. o^pm^p may be connected with a line which, if the drawing is accurate, will converge towards both TN and TR, and, if produced, would meet them at their intersection.

78. While constructing the vanishing point diagram of an object, the student should constantly keep in mind the general statements made in the note under § 69.

Plate IV. should now be solved.

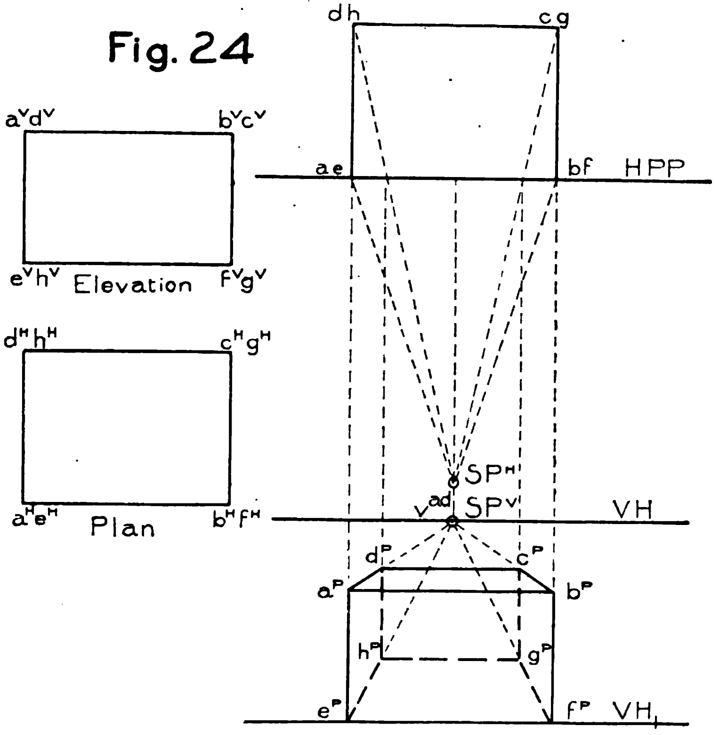
PARALLEL OR ONE-POINT PERSPECTIVE.

79. When the diagram of an object is placed with one of its principal systems of horizontal lines parallel to the picture plane, it is said to be in **Parallel Perspective.** This is illustrated in Fig. 24, by the rectangular block there shown. One system of horizontal lines in the block being parallel to the picture plane, the other system of horizontal lines must be perpendicular to the picture plane. The vanishing point for the latter system will be coincident with SP^V (§ 52). The horizontal system that is parallel to the picture plane will have no vanishing point within finite limits (§ 54, with note; also last paragraph of note under § 69). The third system of lines in the object is a vertical one, and will have no vanishing point within finite limits (§ 54). Thus, of the three systems of lines that form the edges of the block, only one will have a vanishing point within finite limits. This fact has led to the term One-Point Perspective, which is often applied to an object in the position shown in Fig. 24. As will be seen, this

is only a special case of the problems already studied, and the construction of the perspective of an object in parallel perspective is usually simpler than when the diagram is turned at an angle with HPP.

80. The vertical face (*abfe*) of the block lies in the picture plane. It will thus show in its true size and shape (§ 24 *h*). The

Fig. 24



points e^P and f^P will be found on VH$_1$ vertically below the points *e* and *f* in the diagram.

81. Both the edges e^Pa^P and f^Pb^P are lines of measures, and will show the true height of the block, as given by the elevation.

82. The two lines a^Pb^P and e^Pf^P, since they are formed by the intersection of the bases of the block with the picture plane, will also be lines of measures (§ 55), and will show the true length of the block, as given by the plan and elevation.

83. The perspective of the front face of the block, which is

coincident with the picture plane, can be drawn immediately. From a^P, b^P, e^P, and f^P, the horizontal edges, which are perpendicular to the picture plane, will vanish at v^{ad} (coincident with SP^V). The rear vertical edges of the block may be found in the usual manner.

84. The lines a^Pb^P, d^Pc^P, e^Pf^P, and h^Pg^P, which form the horizontal edges parallel to the picture plane, will all be drawn parallel to one another (§ 54, note); and since the lines in space which they represent are horizontal, a^Pb^P, d^Pc^P, e^Pf^P, and h^Pg^P will all be horizontal (see last paragraph of note under § 69).

All of the principles that have been stated in connection with the other problems will apply equally well to an object in parallel perspective.

85. Interior views are often shown in parallel perspective. One wall of the interior is usually assumed coincident with the picture plane, and is not shown in the drawing. For illustration, the rectangular block in Fig. 24 may be considered to represent a hollow box, the interior of which is to be shown in perspective. Assume the face $(a^Pb^Pf^Pe^P)$ that lies in the picture plane to be removed. The resulting perspective projection would show the interior of the box. In making a parallel perspective of an interior, however, VH is usually drawn lower than is indicated in Fig. 24, in order to show the inside of the upper face, or ceiling, of the interior. With such an arrangement, three walls, the ceiling, and the floor of the interior, may all be shown in the perspective projection.

86. Fig. 25 shows an example of interior parallel perspective. The plan of the room is shown at the top of the plate. This has been placed so that it may be used for the diagram, and save the necessity of making a separate drawing. The elevation of the room is shown at the left of the plate, and for convenience it has been placed with its lower horizontal edge in line with VH_1. In this position all vertical dimensions in the object may be carried by horizontal construction lines directly from the elevation to the vertical line of measures (a^Pe^P or b^Pf^P) in the perspective projection.

87. The front face of the room $(a^Pb^Pf^Pe^P)$, which is coincident with the picture plane, may first be established. Each point

in the perspective of this front face will be found to lie vertically under the corresponding point in plan, and horizontally in line with the corresponding point in elevation. Thus, a^P is vertically under a^H, and horizontally in line with a^V.

All lines in the room which are perpendicular to the picture plane vanish at v^{ad} (coincident with SP^V).

Drawing visual rays from every point in the diagram, the corresponding points in the perspective projection will be vertically under the points where these visual rays intersect HPP. The construction of the walls of the room should give the student no difficulty.

. 88. In finding the perspective of the steps, the vertical heights should first be projected by horizontal construction lines from the elevation to the line of measures (a^Pe^P), as indicated by the divisions between e^P and m. These divisions can then be carried along the left hand wall of the room by imaginary horizontal lines vanishing at v^{ad}. The perspective of the vertical edge where each step intersects the left hand wall may now be determined from the plan. Thus, the edge s^Pr^P of the first step is vertically below the intersection of HPP with a visual ray drawn through the point s^H in plan, and is between the two horizontal lines projected from the elevation that show the height of the lower step. The corresponding vertical edge of the second step will be projected from the plan in a similar manner, and will lie between the two horizontal lines projected from the elevation that show the height of the second step, etc.

From s^P the line which forms the intersection of the wall with the horizontal surface of the first step will vanish to v^{ad}, etc.

From r^P the intersection of the first step with the floor of the room will be a line belonging to the same system as a^Pb^P, and will therefore show as a true horizontal line. The point t^P may be projected from the diagram by a visual ray, as usual. From t^P the vertical edge of the step may be drawn till it intersects a horizontal line through s^P, and so on, until the steps that rest against the side wall are determined.

89. The three upper steps in the flight rest against the rear wall. The three upper divisions on the line e^Pm may be carried along the left hand wall of the room, as indicated, till they inter-

sect the rear vertical edge of the wall, represented by the line d^Ph^P. From these intersections the lines may be carried along the rear wall of the room, showing the heights of the three upper steps where they rest against the rear wall.

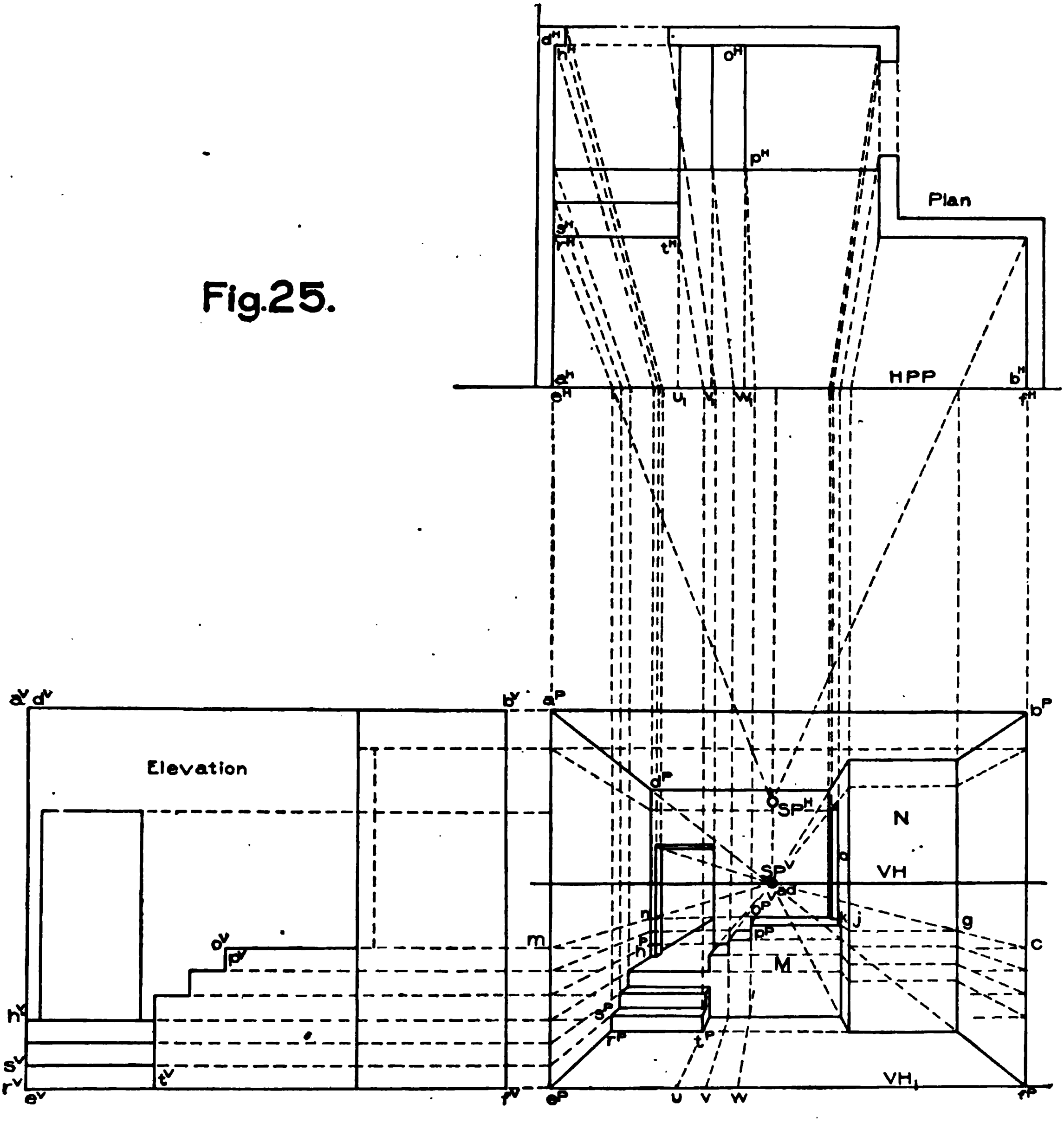
The three upper divisions on the line e^Pm have also been projected across to the line f^Pb^P, and from this line carried by imaginary horizontal lines along the right hand wall of thre room to the plane N, across the plane N to the plane O, and from the plane O to the plane M. Thus, for illustration, the upper division, representing the height of the upper step, has been carried from m to c; from c to g along the right hand face of the wall; from g to j along the plane N; from j to k on the plane O, and from k to p^P on the plane M.

The point p^P is where the line which represents the height of the upper step meets a vertical dropped from the intersection of HPP with a visual ray through the point p^H in the diagram. p^P is one corner in the perspective of the upper step, the visible edges of the step being represented by a horizontal line, p^Pk, a line (p^Po^P) vanishing at v^{ad}, and a vertical line drawn from p^P between the two horizontal lines on the plane H, which represent the height of the upper step. The point o^P is at the intersection of the line drawn through p^P, vanishing through v^{ad}, with the horizontal line on the rear wall drawn through the point n, and representing the upper step where it rests against the rear wall.

The remaining steps may be found in a similar manner. The student should have no difficulty in following out the construction, which is all shown on the plate..

90. The position of the point t^P on the line r^Pt^P was determined by projecting in the usual manner from the diagram. The position of t^P might have been found in the following manner: In the figure the line e^Pf^P is a line of measures (§ 81), and divisions on this line will show in their true size. Thus, if we imagine a horizontal line to be drawn through t^P, parallel to the wall of the room, it will intersect e^Pf^P in the point u. Since e^Pu is on a line of measures, it will show in its true length. Thus, t^P might have been determined by laying off e^Pu equal to the distance e^Hu_1 taken from the plan, and then drawing through the point u a line van-

Fig.25.



Plan
dH
hH
oH
pH
sH
rH
tH
aH
eH
u1
v1
w1
HPP
bH
fH
Elevation
aV dV
bV
hV
sV
rV
eV
tV
oV
pV
fV
aP
bP
dP
SPH
SPV
N
VH
ad
oP
pP
M
n
m
h
k
j
g
c
rP
tP
eP
u
v
w
VH1
fP

ishing at v^{ad}. The intersection of this line with the horizontal line drawn through r^P will determine t^P.

In a similar manner the vertical edges of the steps, where they intersect the plane M, might have been found by laying off from u, on e^Pf^P, the divisions uv and vw taken from the plan. These divisions could have been carried along the floor by horizontal lines parallel to the sides of the room (vanishing at v^{ad}), to the plane M, and then projected vertically upward on the plane M, as indicated in the figure.

Solve Plate V.

METHOD OF PERSPECTIVE PLAN.

91. In the foregoing problems the perspective projection has been found from a diagram of the object. Another way of constructing a perspective projection is by the method of **Perspective Plan.** In this method no diagram is used, but a perspective plan of the object is first made, and from this perspective plan the perspective projection of the object is determined. The perspective plan is usually supposed to lie in an auxiliary horizontal plane below the plane of the ground. The principles upon which its construction is based will now be explained.

92. In Fig. 26, suppose the rectangle $a^Hb^Hc^Hd^H$ to represent the horizontal projection of a rectangular card resting upon a horizontal plane. The diagram of the card is shown at the upper part of the figure. It will be used only to explain the construction of the perspective plan of the card.

First consider the line ad, which forms one side of the card. On HPP lay off from a, to the left, a distance (ae) equal to the length of the line ad. Connect the points e and d. ead is by construction an isosceles triangle lying in the plane of the card, with one of its equal sides (ae) in the picture plane. Now, if this triangle be put into perspective, the side ad, being behind the picture plane, will appear shorter than it really is; while the side ae, which lies in the picture plane, will show in its true length.

Let VH_1 be the vertical trace of the plane on which the card and triangle are supposed to rest. The position of the station point is shown by its two projections SP^H and SP^V. The vanishing point for the line *ad* will be found at v^{ad} in the usual manner. In a similar way, the vanishing point for the line *ed*, which forms the base of the isosceles triangle, will be found at v^{ed}, as indicated. a^P will be found on VH_1 vertically under the point *a*, which forms the apex of the isosceles triangle *ead*. The line a^Pd^P will vanish at v^{ad}. The point e^P will be found vertically

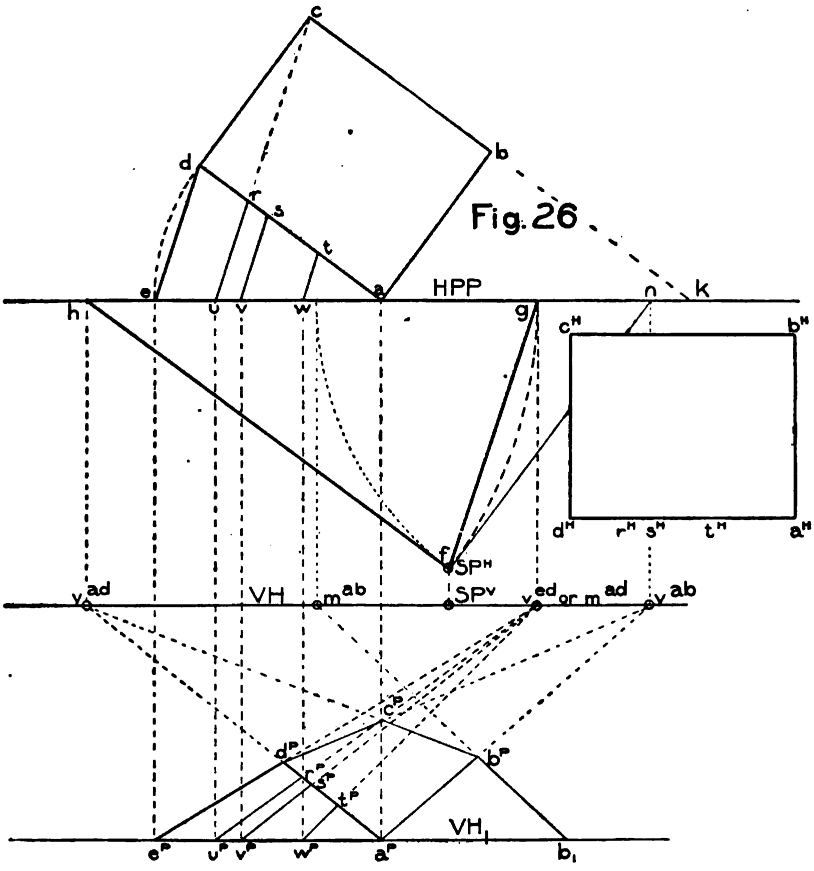


Fig. 26.

below the point *e*. e^Pd^P will vanish at v^{ed}, and determine by its intersection with a^Pd^P the length of that line. $e^Pa^Pd^P$ is the perspective of the isosceles triangle *ead*.

If the line *ad* in the diagram is divided in any manner by the points *t*, *s*, and *r*, the perspectives of these points may be found on the line a^Pd^P in the following way. If lines are drawn through the points t, s, and r in the diagram parallel to the base de of the isosceles triangle (ead), these lines will divide the line ae in a manner exactly similar to that in which the line ad is divided. Thus, aw will equal at, wv will equal ts, etc. Now, in the perspective projection of the isosceles triangle, a^Pe^P lies in the picture plane. It will show in its true length, and all divisions on it will show in their true size. Thus, on a^Pe^P lay off a^Pw^P, w^Pv^P, and v^Pu^P equal to the corresponding distances at, ts, and sr, given in the diagram. Lines drawn through the points w^P, v^P, and u^P, vanishing at v^{ed}, will be the perspective of the lines wt, vs, and ur in the isosceles triangle, and will determine the positions of t^P, s^P, and r^P, by their intersections with a^Pd^P.

93. It will be seen that after having found v^{ad} and v^{ed}, the perspective of the isosceles triangle can be found without any reference to the diagram. Assuming the position of a^P at any desired point on VH_1, the divisions a^P, w^P, v^P, u^P, e^P may be laid off from a^P directly, making them equal to the corresponding divisions a^H, t^H, s^H, r^H, d^H, given in the plan of the card. A line through a^P vanishing at v^{ad} will represent the perspective side of the isosceles triangle. The length of this side will be determined by a line drawn through e^P, vanishing at v^{ed}. The positions of t^P, s^P, and r^P may be determined by lines drawn through w^P, v^P, and u^P, vanishing at v^{ed}.

94. It will be seen that the lines drawn to v^{ed} serve to measure the perspective distances $a^P\ t^P$, $t^P\ s^P$, $s^P\ r^P$, and $r^P\ d^P$, on the line a^Pd^P, from the true lengths of these distances as laid off on the line a^Pe^P. Hence the lines vanishing at v^{ed} are called **Measure Lines** for the line a^Pd^P, and the vanishing point v^{ed} is called a **Measure Point** for a^Pd^P.

95. Every line in perspective has a measure point, which may be found by constructing an isosceles triangle on the line in a manner similar to that just explained.

NOTE. — The vanishing point for the base of the isosceles triangle always becomes the measure point for the side of the isosceles triangle which does not lie in HPP.

96. All lines belonging to the same system will have the same measure point. Thus, if the line bc, which is parallel to ad, be continued to meet HPP, and an isosceles triangle (cku) con

structed on it, as indicated by the dotted lines in the figure, the base (*uc*) of this isosceles triangle will be parallel to *de*, and its vanishing point will be coincident with v^{de}.

97. There is a constant relation between the vanishing point of a system of lines and the measure point for that system. Therefore, if the vanishing point of a system of lines is known, its measure point may be found without reference to a diagram, as will be explained.

In constructing the vanishing points v^{ad} and v^{ed}, *fh* was drawn parallel to *ad*, *fg* was drawn parallel to *ed*, and since *hg* is coincident with HPP, the two triangles *ead* and *fhg* must be similar. As *ae* was made equal to *ad* in the small triangle, *hf* must be equal to *hg* in the large triangle; and consequently v^{ed}, which is as far from v^{ad} as *g* is from *h*, must be as far from v^{ad} as the point *f* is from the point *h*.

If the student will refer back to Figs. 8, 9, and 9a, he will see that the point *h* bears a similar relation in Fig. 26 to that of the point m^{H} in Figs. 8, 9, and 9a, and that the point *h* in Fig. 26 is really the horizontal projection of the vanishing point v^{ad}. (See also § 32.) Therefore, as v^{ed} is as far from v^{ad} as the point *h* is from the point *f*, we may make the following statement, which will hold for all systems of horizontal lines.

98. *The measure point for any system of horizontal lines will be found on VH as far from the vanishing point of the system as the horizontal projection of that vanishing point is distant from the horizontal projection of the station point.*

NOTE. — In accordance with the construction shown in Fig. 26, SP^{V} will always lie between the vanishing point of a system and its measure point.

99. The measure point of any system of lines is usually denoted by a small letter *m* with an index corresponding to its related vanishing point. Thus, m^{ab} signifies the measure point for the system of lines vanishing at v^{ab}.

100. The vanishing point for *ab* in Fig. 26 has been found at v^{ab}. The point *n*, in HPP, is the horizontal projection of this vanishing point. The measure point (m^{ab}) for all lines vanishing at v^{ab} will be found on VH, at a distance from v^{ab} equal to the distance from *n* to SP^{H} (98). In accordance with this statement,

m^{ab} has been found by drawing an arc with n as center, and with a radius equal to the distance from n to SP^H, and dropping from the intersection of this arc with HPP a vertical line. m^{ab} is found at the intersection of this vertical line with VH.

101. The perspective of ab has been drawn from a^P, vanishing at v^{ab}. a^Pb_1 on VH_1 is made equal to the length of a^Hb^H given in the plan of the card. A measure line through b_1, vanishing at m^{ab}, will determine the length of a^Pb^P. A line from b^P vanishing at v^{ad}, and one from d^P vanishing at v^{ab}, will intersect at c^P, completing the perspective plan of the card.

102. Even the vanishing points (v^{ab} and v^{ad}) for the sides of the card may be found without drawing a diagram. Since fn is drawn parallel to ab, it makes the same angle with HPP that ab makes. Similarly, since fh is drawn parallel to ad, it makes the same angle with HPP that ad makes. The angle between fn and fh must show the true angle made by the two lines ab and ad in the diagram. Therefore, having assumed SP^H, we have simply to draw two lines through SP^H, making with HPP the respective angles that the two sides of the cards are to make with the picture plane, care being taken that the angle these two lines make with one another shall equal the angle shown between the two sides of the card in the given plan. Thus, in Fig. 27, the two projections of the station point have first been assumed. Then through SP^H, two lines (fn and fh) have been drawn, making respectively, with HPP, the angles (H° and N°) which it is desired the sides of the card shall make with the picture plane, care being taken to make the angle between fn and fh equal to a right angle, since the card shown in the given plan is rectangular.

Verticals dropped to VH from the points n and h will determine v^{ab} and v^{ad}. Having found v^{ab} and v^{ad}, m^{ab} and m^{ad} should next be determined, as explained in § 98. VH_1 should now be assumed, and a^P chosen at any point on this line. It is well not to assume a^P very far to the right or left of an imaginary vertical line through SP^V.

From a^P the sides of the card will vanish at v^{ab} and v^{ad} respectively. Measure off from a^P on VH_1, to the right, a distance (a^Pb_1) equal to the length of the side a^Hb^H shown in the given plan. A measure line through b_1, vanishing at m^{ab}, will determine the length of $a^P b^P$. Measure off from a^P on VH_1, to the left, a distance ($a^P d_1$) equal to the length of the side $a^H d^H$ shown in the given plan. A measure line through d_1 vanishing at m^{ad}, will determine the length of $a^P d^P$.

From b^P and d^P, the remaining sides of the card vanish to v^{ad} and v^{ab} respectively, determining by their intersection the point c^P.

The line $a^H d^H$ in plan is divided by points t^H, s^H, and r^H. To divide the perspective ($a^P d^P$) of this line in a similar manner, lay off on VH_1 from a^P, to the left, the divisions t_1, s_1, and r_1, as taken from the given plan. Measure lines through t_1, s_1, and r_1, vanishing at m^{ad}, will intersect $a^P d^P$, and determine t^P, s^P, and r^P.

103. As has already been stated, the true length of any line is always measured on VH_1, and from the true length, the length of the perspective projection of the line is determined by measure lines vanishing at the measure point for the line whose perspective is being determined. Care must be taken to measure off the true length of the line in the proper direction. The general rule for doing this is as follows: —

If the measure point of any line is at the *right* of SP^V, the true length of the line will be laid off on VH_1 in such a manner that measurements for the *more distant* points in the line will be to the *left* of the measurements for the *nearer* points.

Thus, m^{ad} is at the *right* of SP^V. The point d^P is more distant than the point t^P. Therefore, the measurement (d_1) for the point d^P will be to the *left* of the measurement for the point t^P. In other words, since m^{ad} is to the *right* of SP^V, d_1, which represents a point more distant than t_1, must be to the *left* of t_1, the distance between t_1 and d_1 being equal to the true length of $t^P d^P$, as shown by $t^H d^H$ in the given plan.

On the other hand, if the measure point for any system of lines is to the *left* of SP^V, the true measurements for any line of the system should be laid off on VH_1 in such a manner that measurements for more *distant points* on the line are to the *right* of measurements for the *nearer* points of the line.

Thus, m^{ab} is to the *left* of SP^V. The point b^P is *more distant* than the point a^P. Therefore, b_1, which shows the true measurement for the point b^P, must be laid off to the *right* of a^P.

104. It sometimes happens that a line extends in front of the picture plane, as has already been seen in the lines of the nearest corner of the porch in Fig. 22. It may be desired to extend the line a^Pd^P in Fig. 27, in front of the picture plane, to the point y^P, as indicated in the perspective projection. In this case, the point a^P being *more distant* than the point y^P, and m^{ad} being to the *right* of SP^V, the true measurement of a^Py^P must be laid off on VH_1 in such a manner that the measurement for a^P will be to the *left* of the measurement for y^P. In other words, y_1 must be on VH_1 to the right of a^P, the distance a^Py_1 showing the true length of a^Py^P.

NOTE. — The true length of any line which extends in front of the picture plane will be *shorter* than the perspective of the line.

105. Having determined the perspective of any line, as d^Pc^P, its true length may be determined by drawing measure lines through d^P and c^P. The distance intercepted on VH_1 by these measure lines will show the true length of the line. Thus, d^Pc^P vanishes at v^{ab}. Its measure point must therefore be m^{ab}. Two lines drawn from m^{ab}, and passing through c^P and d^P respectively, will intersect VH_1 in the points c_1 and d_2. The distance between c_1 and d_2 is the true length of c^Pd^P. This distance will be found equal to a^Pb_1, which is the true measure for the opposite and equal side (a^Pb^P) of the rectangle.

In a similar manner, the true length of b^Pc^P may be found by drawing measure lines from m^{ad} through b^P and c^P respectively. b_2c_2 will show the true length of c^Pb^P, and should be equal to a^Pd_1, which is the true length of the opposite and equal side (a^Pd^P) of the rectangle.

106. The perspective (w^P) of a point on one of the rear edges of the card may be determined in either of the following ways: —

1st. From b_2, which is the intersection with VH_1 of the measure line through b^P, lay off on VH_1, to the left (§ 103), the distance b_2w_2 equal to the b^Hw^H taken from the given plan. A measure line through w_2, vanishing at m^{ad}, will intersect c^Pb^P at the point w^P.

2d. In the given plan draw a line through w^H, parallel to a^Hb^H, intersecting a^Hd^H in the point w_4. On VH_1 make a^Pw_1 equal to a^Hw_4, as given in the plan. A measure line through w_1, vanishing at m^{ad}, will determine w_3 on a^Pd^P. From w_3, a line parallel to a^Pb^P (vanishing at v^{ab}) will determine, by its intersection with b^Pc^P, the position of w^P.

107. In making a perspective by the method of perspective plan, it is generally customary to assume VH and HPP coincident. That is to say, the coordinate planes are supposed to be in the position shown in Fig. 9, instead of being drawn apart as indicated in Fig. 9a. This arrangement simplifies the construction somewhat.

This is illustrated in Fig. 28, which shows a complete problem in the method of perspective plan. Compare this figure with Fig. 27, supposing that, in Fig. 27, HPP with all its related horizontal projections could be moved downward, until it just coincides with VH. The point n would coincide with v^{ab}, h with v^{ad}, and the arrangement would be similar to that shown in Fig. 28. All the principles involved in the construction of the measures, points, etc., would remain unchanged.

108. The vanishing points in Fig. 28 have first been assumed, as indicated at v^{ab} and v^{ad}. As the plan of the object is rectangular, SP^H may be assumed at any point on a semicircle constructed with $v^{ab}v^{ad}$ as diameter. By assuming SP^H in this manner, lines drawn from it to v^{ab} and v^{ad} respectively must be at right angles to one another, since any angle that is just contained in a semicircle must be a right angle. These lines show by the angles they make with HPP, the angles that the vertical walls of the object in perspective projection will make with the picture plane (§ 102).

109. m^{ad} and m^{ab} have been found, as explained in § 97, in accordance with the rule given in § 98.

VH_2 should next be assumed at some distance below VH, to represent the vertical trace of the horizontal plane on which the perspective plan is to be made (§ 91).

The position of a^P (on VH_2) may now be assumed, and the

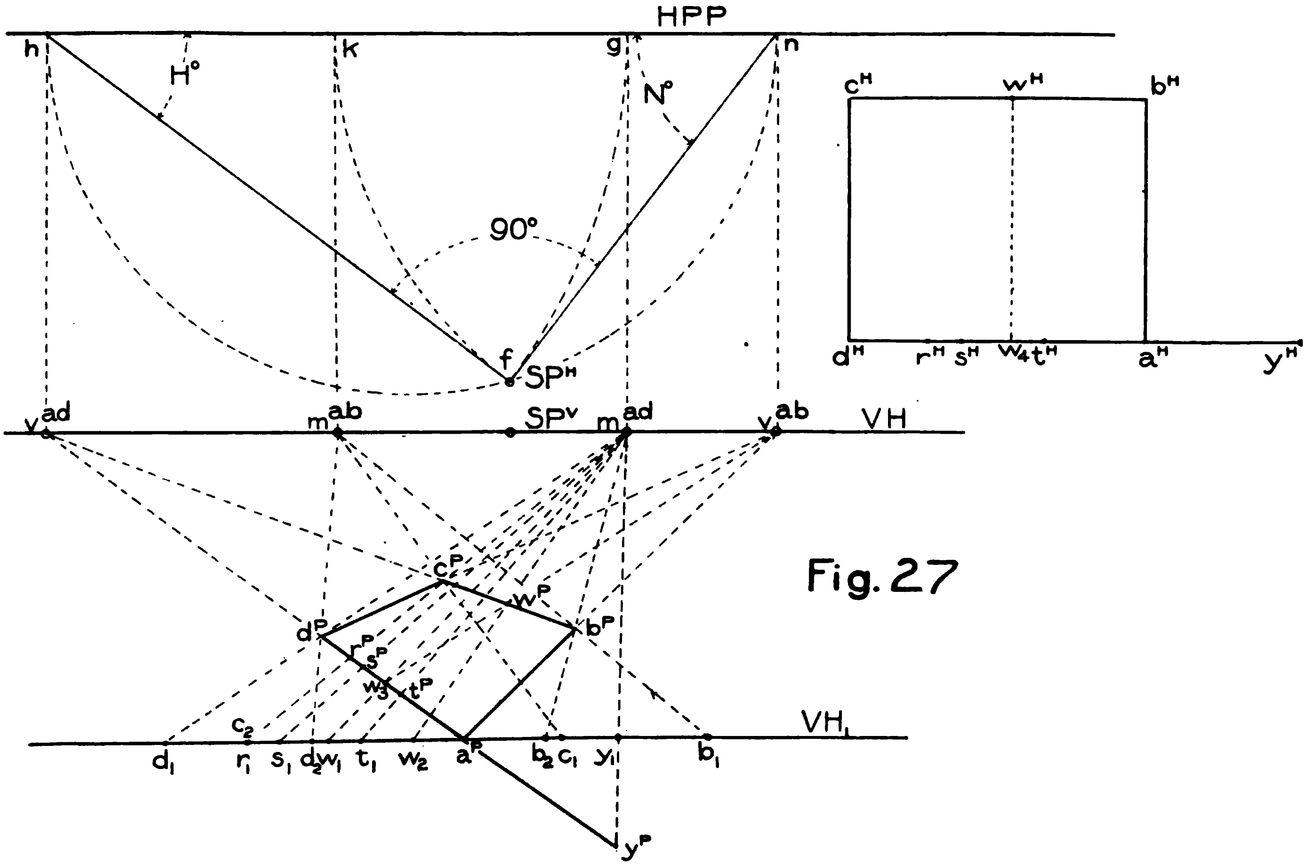
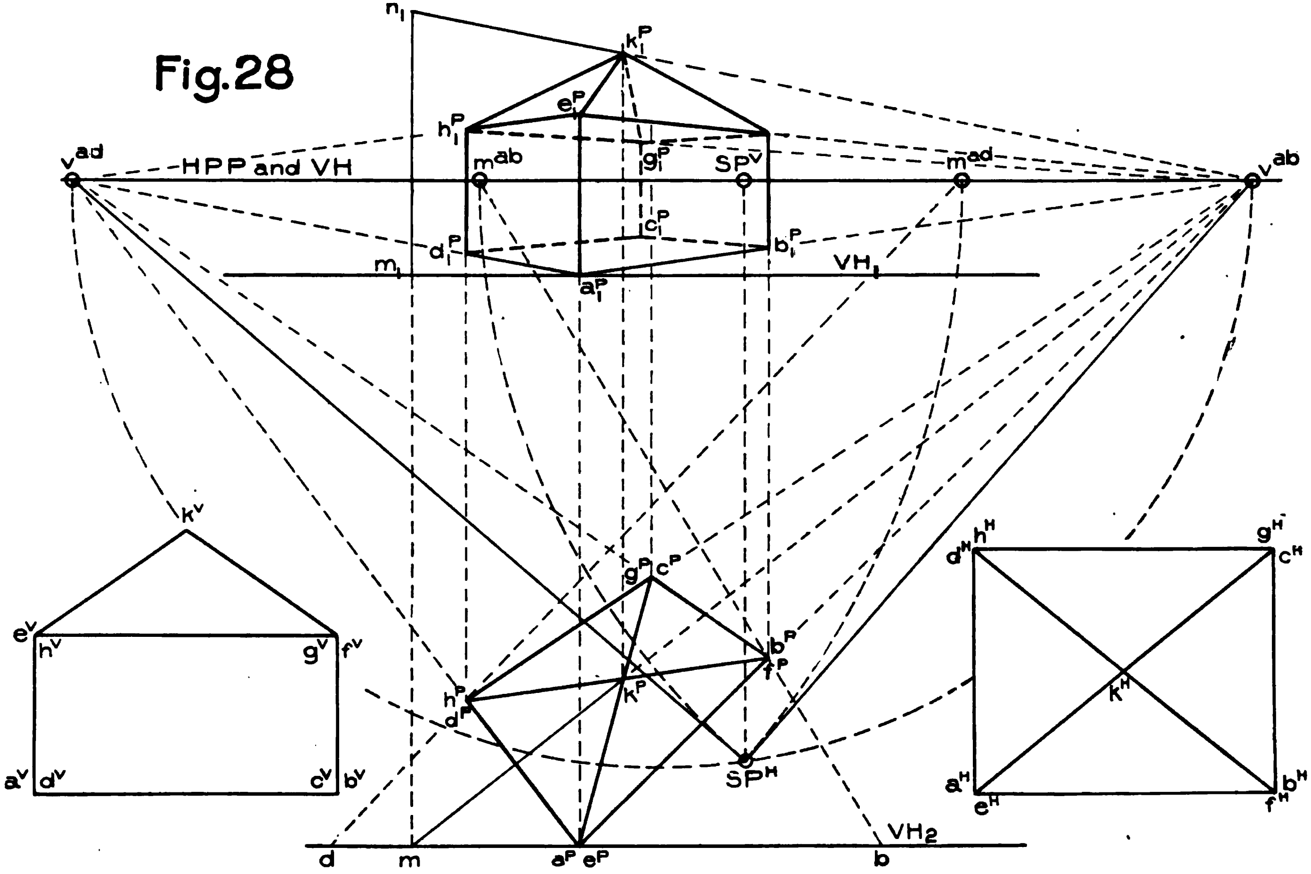

HPP
h
H°
k
g
N°
n
90°
f
SPᴴ
cᴴ
wᴴ
bᴴ
dᴴ
rᴴ
sᴴ
w₄tᴴ
aᴴ
yᴴ
vad
mab
SPᵛ
mad
vab
VH
cᴾ
wᴾ
dᴾ
bᴾ
rᴾ
sᴾ
w₃
tᴾ
c₂
VH₁
d₁
r₁
s₁
d₂w₁
t₁
w₂
aᴾ
b₂c₁
y₁
b₁
yᴾ

Fig. 27

Fig.28



n₁
k₁ᴾ
eᴾ
h₁ᴾ
Vᵃᵈ
HPP and VH
mᵃᵇ
g₁ᴾ
SPⱽ
mᵃᵈ
Vᵃᵇ
c₁ᴾ
d₁ᴾ
b₁ᴾ
m₁
a₁ᴾ
VH₁
kⱽ
eⱽ
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gᴾ cᴾ
bᴾ
fᴾ
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kᴾ
SPᴴ
dᴴ hᴴ
gᴴ
cᴴ
kᴴ
aᴴ
eᴴ
bᴴ
fᴴ
VH₂
d
m
aᴾ eᴾ
b

perspective plan of the object constructed from the given plan, exactly as was done in the case of the rectangular card in Fig. 27.

110. Having constructed the complete perspective plan, every point in the perspective projection of the object will be found *vertically* above the corresponding point in the perspective plan.

VH_1 is the vertical trace of the plane on which the perspective projection is supposed to rest. a_1^p is found on VH_1 vertically over a^p in the perspective plan. $a_1^p e_1^p$ is a vertical line of measures for the object, and shows the true height given by the elevation.

To find the height of the apex (k_1^p) of the roof, imagine a horizontal line parallel to the line ab to pass through the apex, and to be extended till it intersects the picture plane. A line drawn through k^p, vanishing at v^{ab}, will represent the perspective plan of this line, and will intersect VH_2 in the point m, which is the perspective plan of the point where the horizontal line through the apex intersects the picture plane. The vertical distance n_1m_1, laid off from VH_1, will show the true height of the point k above the ground. k_1^p will be found vertically above k^p, and on the line through n_1 vanishing at v^{ab}. The student should find no difficulty in following the construction for the remainder of the figure.

111. Fig. 29 illustrates another example of a similar nature to that in Fig. 28. The student should follow carefully through the construction of each point and line in the perspective plan and in the perspective projection. The problem offers no especial difficulty.

Plate VI. should now be solved.

CURVES.

112. Perspective is essentially a science of straight lines. If curved lines occur in a problem, the simplest way to find their perspective is to refer the curves to straight lines.

If the curve is of simple, regular form, such as a circle or an ellipse, it may be enclosed in a rectangle. The perspective of the enclosing rectangle may then be found. A curve inscribed within this perspective rectangle will be the perspective of the given curve.

Fig. 30 shows a circle inscribed in a square. The points of intersection of the diameters with the sides of the square give the four points of tangency between the square and circle. The sides of the square give the directions of the circle at these points. Additional points on the circle may be established by drawing the diagonals of the square, and through the points m^H, k^H, n^H, and h^H drawing construction lines parallel to the sides of the square, as indicated in the figure.

Fig. 30

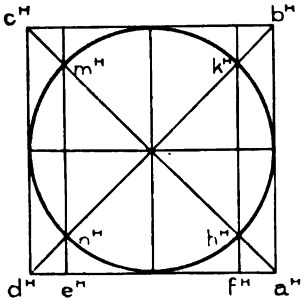


Fig. 31 shows the square, which is supposed to lie in a horizontal plane, in parallel perspective. One side of the square (a^Pd^P) lies in the picture plane, and will show in its true size. The vanishing point for the sides perpendicular to the picture plane will coincide with SP^V (§ 52, note). The measure point for these sides has been found at m^{ab}, in accordance with principles already explained. a^Pb_1 is laid off on VH_1 to the right of the point a^P, equal to the true length of the side of the square. A measure line through b_1, vanishing at m^{ab}, will determine the position of the point b^P. b^Pc^P will be parallel to a^Pd^P (§ 54, note).

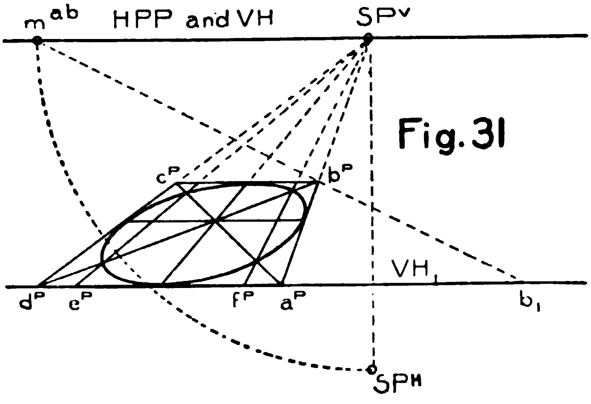


Fig. 31

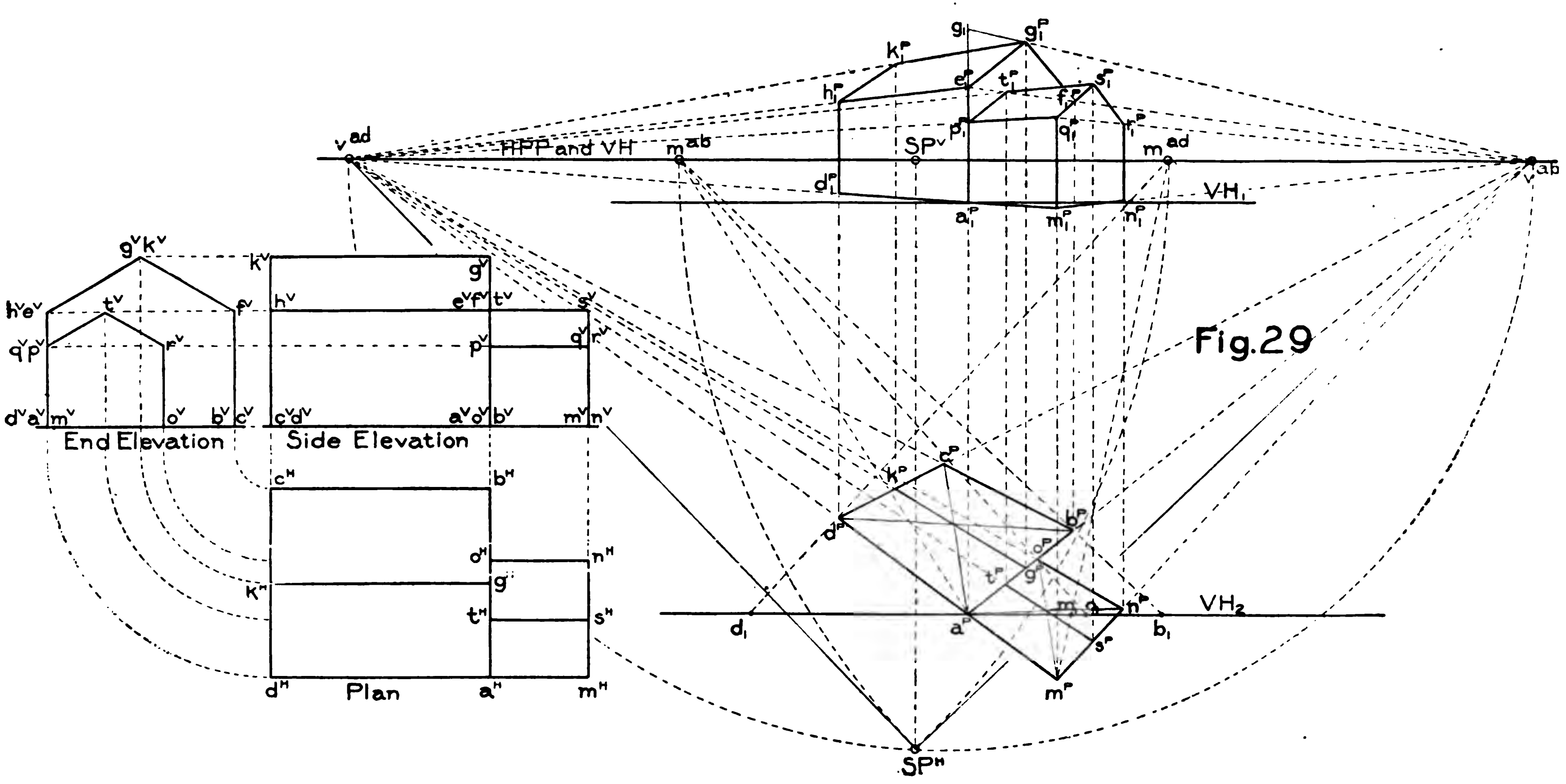

End Elevation
Side Elevation
Plan
HPP and VH
VH₁
VH₂
SPᵛ
SPᴴ
vᵃᵈ
vᵃᵇ
mᵃᵇ
mᵃᵈ
d₁
b₁
g₁

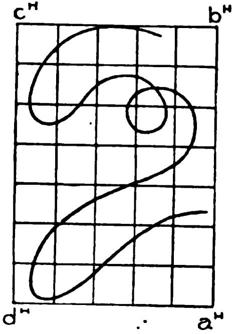
Fig. 29

The diagonals of the square may be drawn. Their intersection will determine the perspective center of the square. The diameters will pass through this perspective center, one vanishing at SP^V, and the other being parallel to a^Pd^P (§ 54, note).

The divisions d^Pe^P and a^Pf^P will show in their true size. Lines through e^P and f^P, vanishing at SP^V, will intersect the diagonals of the square, giving four points on the perspective of the circle. Four other points on the perspective of the circle will be determined by the intersections of the diameter with the sides of the square. The perspective of the curve can be drawn as indicated.

113. If the curve is of very irregular form, such as that shown in Fig. 32, it can be enclosed in a rectangle, and the rectangle divided by lines, drawn parallel to its sides, into smaller rectangles, as indicated in the figure.

Fig.32



The perspective of the rectangle with its dividing lines may then be found, and the perspective of the curve drawn in free hand. This is shown in Fig. 33. If very great accuracy is required, the perspectives of the exact points where the curve crosses the dividing lines of the rectangle may be found.

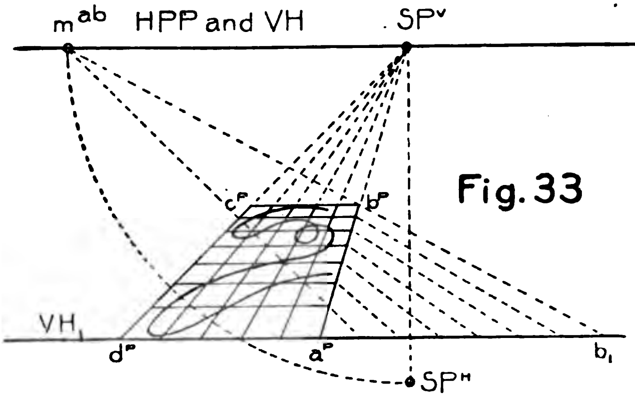


Fig.33

APPARENT DISTORTION.

114. There seems to exist in the minds of some beginners in the study of perspective, the idea that the drawing of an object made in accordance with geometrical rules may differ essentially from the appearance of the object in nature. Such an idea is erroneous, however. The only difference between the appearance of a view in nature and its correctly constructed perspective projection is that the view in nature may be looked at *from any point*, while its perspective representation shows the view as seen from one particular point, and from that point only.

For every new position that the observer takes, he will see a new view of the object in space, his eye always being at the apex of the cone of visual rays that projects the view he sees (see Fig. 1). In looking at an object in space, the observer may change his position as often as he likes, and will see a new view of the object for every new position that he takes.

115. This is not true of the perspective projection of the object, however. Before making a perspective drawing, the position of the observer's eye, or station point, must be decided upon, and the resulting perspective projection will represent the object as seen from this point, and from this point only. The observer, when looking at the drawing, in order that it may correctly represent to him the object in space, must place his eye exactly at the assumed position of the station point. If the eye is not placed exactly at the station point, the drawing will not appear absolutely correct, and under some conditions will appear much distorted or exaggerated.

116. Just here lies the defect in the science of perspective. It is the assumption that the observer has but one eye. Practically, of course, this is seldom the case. A drawing is generally seen with two eyes, and the casual observer never thinks of placing his eye in the proper position. Even were he inclined to do so, it would generally be beyond his power, as the position of the station point is seldom shown on the finished drawing.

117. As an illustration of apparent distortion, consider the perspective projection shown in Fig. 23. In order that the perspectives of the vanishing points might fall within the rather

narrow limits of the plate, the station point in the figure has been assumed very close to the picture plane, the distance from HPP to SP^H showing the assumed distance from the paper at which the observer should place his eye in order to obtain a correct view of the perspective projection. This distance is so short it is most improbable that the observer will ordinarily place his eye in the proper position when viewing the drawing. Consequently the perspective projection appears more or less unnatural or distorted. But, for the sake of experiment, if the student will cut a small, round hole, one quarter of an inch in diameter, from a piece of cardboard, place it directly in front of SP^V and at a distance from the paper equal to the distance of SP^H from HPP, and if he will then look at the drawing through the hole in the cardboard, closing the eye he is not using, he will find that the unpleasant appearance of the perspective projection disappears.

It will thus be seen that unless the observer's eye is in the proper position while viewing a drawing, the perspective projection may give a very unsatisfactory representation of the object in space.

118. If the observer's eye is not very far removed from the correct position, the apparent distortion will not be great, and in the majority of cases will be unnoticeable. In assuming the position for the station point, care should be taken to choose such a position that the observer will naturally place his eyes there when viewing the drawing.

119. As a person naturally holds any object at which he is looking directly in front of his eyes, the first thought in assuming the station point should be to place it so that it will come very nearly in the center of the perspective projection.

120. Furthermore, the normal eye sees an object most distinctly when about ten inches away. As one will seldom place a drawing nearer to his eye than the distance of distinct vision, a good general rule is to make the *minimum* distance between the station point and the picture plane about ten inches. For a small drawing, ten inches will be about right; but, as the drawing increases in size, the observer naturally holds it farther and farther from him, in order to embrace the whole without having to turn his eye too far to the right or left.

121. Sometimes a general rule is given to make the distance of the station point equal to the altitude of an equilateral triangle, having the extreme dimensions of the drawing for its base, and the station point for its apex.

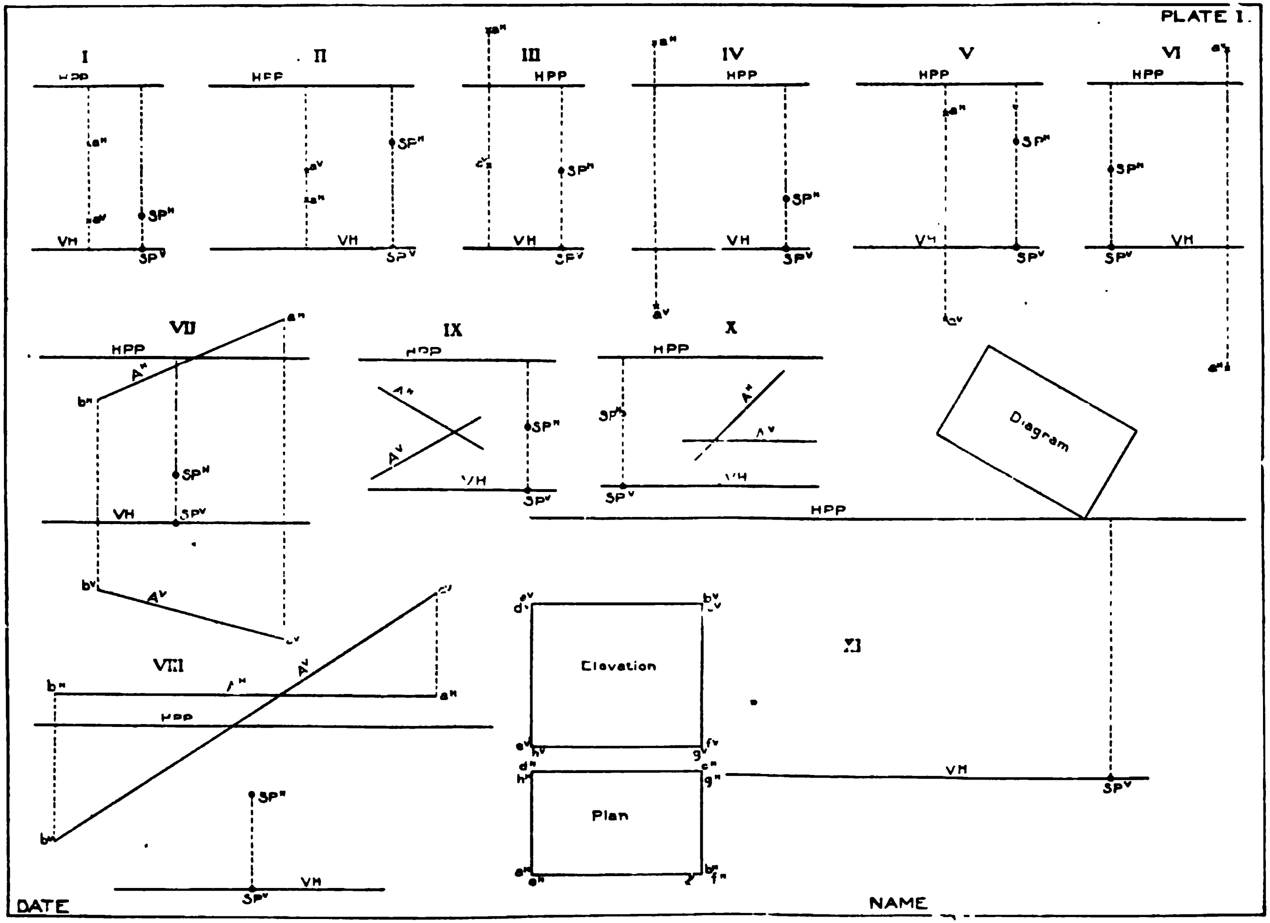
122. The apparent distortion is always greater when the assumed position of the observer's eye is too near than when it is too far away. In the former case, objects do not seem to diminish sufficiently in size as they recede from the eye. On the other hand, if the observer's eye is between the assumed position of station point and the picture plane, the effect is to make the objects diminish in size somewhat too rapidly as they recede from the eye. This effect is not so easily appreciated nor so disagreeable as the former. Therefore it is better to choose the position of the station point too far away, rather than too near.

123. Finally, the apparent distortion is more noticeable in curved than in straight lines, and becomes more and more disagreeable as the curve approaches the edge of the drawing. Thus, if curved lines occur, great pains should be taken in choosing the station point; and, if possible, such a view of the object should be shown that the curves will fall near the center of the perspective.

124. The student should realize that the so-called distortion in a perspective projection is only an apparent condition. If the eye of the observer is placed exactly at the position assumed for it when making the drawing, the perspective projection will exactly represent to him the corresponding view of the object in space.

EXAMINATION PAPER

PLATE I.



DATE

NAME

PERSPECTIVE DRAWING.

Data to be used by student in solving plates. Leave all necessary construction lines. Letter all points, vanishing points, lines, etc., as found, in accordance with the notation given in the Instruction Paper.

PLATE I.

PROBLEMS I., II., III., IV., V., and VI. **Find the perspective of the point *a*. Also in each problem locate the positions of the point *a*, and of the station point, as follow:—**

$$a\begin{cases} \text{—— inches} \left\{\begin{matrix}\text{behind}\\ \text{or}\\ \text{in front}\end{matrix}\right\} \text{of picture plane.} \\ \text{—— inches} \left\{\begin{matrix}\text{above}\\ \text{or}\\ \text{below}\end{matrix}\right\} \text{the plane of the horizon.}\end{cases}$$

Station point —— inches in front of the picture plane.

PROBLEMS VII. and VIII. **Find the perspective of the line A.**

PROBLEMS IX. and X. **Find the perspective of the vanishing point of the system of lines parallel to the given line A.**

PROBLEM XI. **Find from the given plan and elevation the perspective projection of the rectangular block.**

The view to be shown is indicated by the diagram. The station point is to be $3\frac{3}{4}$ inches in front of the picture plane. The position of SP^{V} is given. The perspective projection is to rest upon a horizontal plane 2 inches below the level of the eye. Invisible lines in the perspective projection should be dotted.

PLATE II.

PROBLEM XII. **To find the perspective of a cube the sides of which are 1¾ inches long, resting on a horizontal plane 1 inch below the observer's eye.**

The nearest edge of the cube is about 1⅛ inches behind the picture plane, as shown by the relation between the given diagram and HPP. The station point is to be 3¾ inches in front of the picture plane. The position of SP^V is given. Invisible edges of the cube should be dotted in the perspective projection.

PROBLEM XIII. **To find the perspective of a cube similar to that in the last problem.**

The position of the cube is such that it intersects the picture plane as indicated by the relation between the given diagram and HPP. The cube is supposed to rest on the horizontal plane represented by VH_1. The station point is to be 3¾ inches in front of the picture plane. The position of SP^V is given. Invisible edges should be dotted in the perspective projection.

PROBLEM XIV. **Block pierced by a rectangular hole.**

The plan and elevation given in the figure represent a rectangular block pierced by a rectangular hole which runs horizontally through the block from face to face, as indicated. The diagram, HPP, and the position of SP^V are given. The block is to rest on a horizontal plane 2⅝ inches below the observer's eye. The observer's eye is to be 6½ inches in front of the picture plane. Find the perspective projection of the block and of the rectangular hole. All invisible lines in the perspective projection should be dotted.

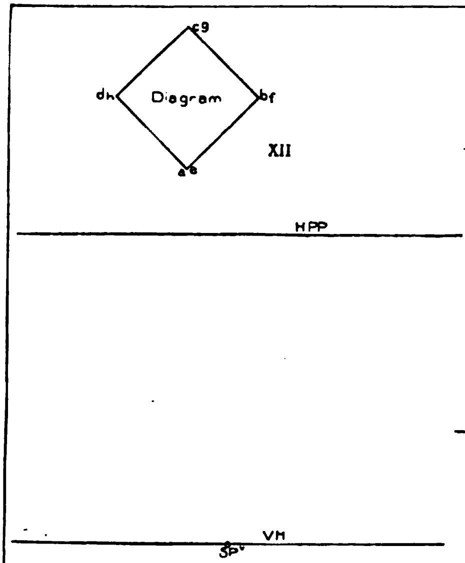
PLATE III.

PROBLEM XV. **Find the perspective projection of the house shown in plan, side and end elevations.**

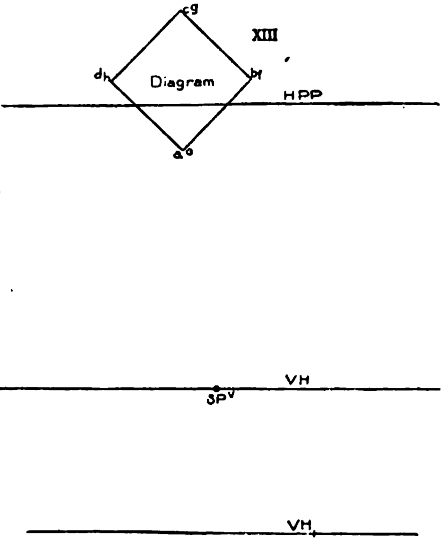
The diagram, HPP, and the projections of the station point are given. The house is supposed to rest on a horizontal plane $1\frac{3}{16}$ inch below the observer's eye. Invisible lines in this perspective projection need not be shown except as they may be needed for construction. All necessary construction lines should be shown; but the points in the perspective projection need not be lettered, except a^P, b^P, e^P, and d^P.

PLATE II

XII



XIII



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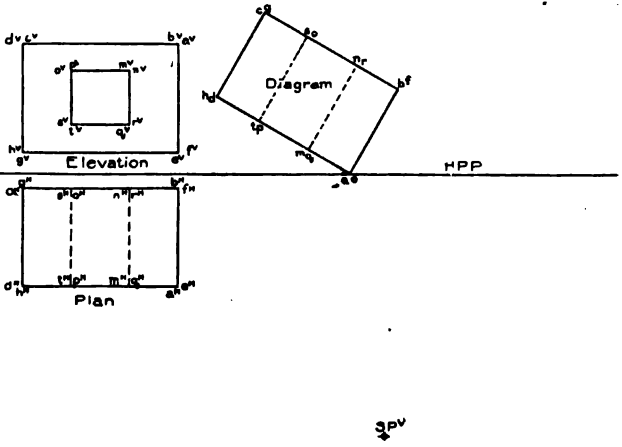

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PLATE III

XV

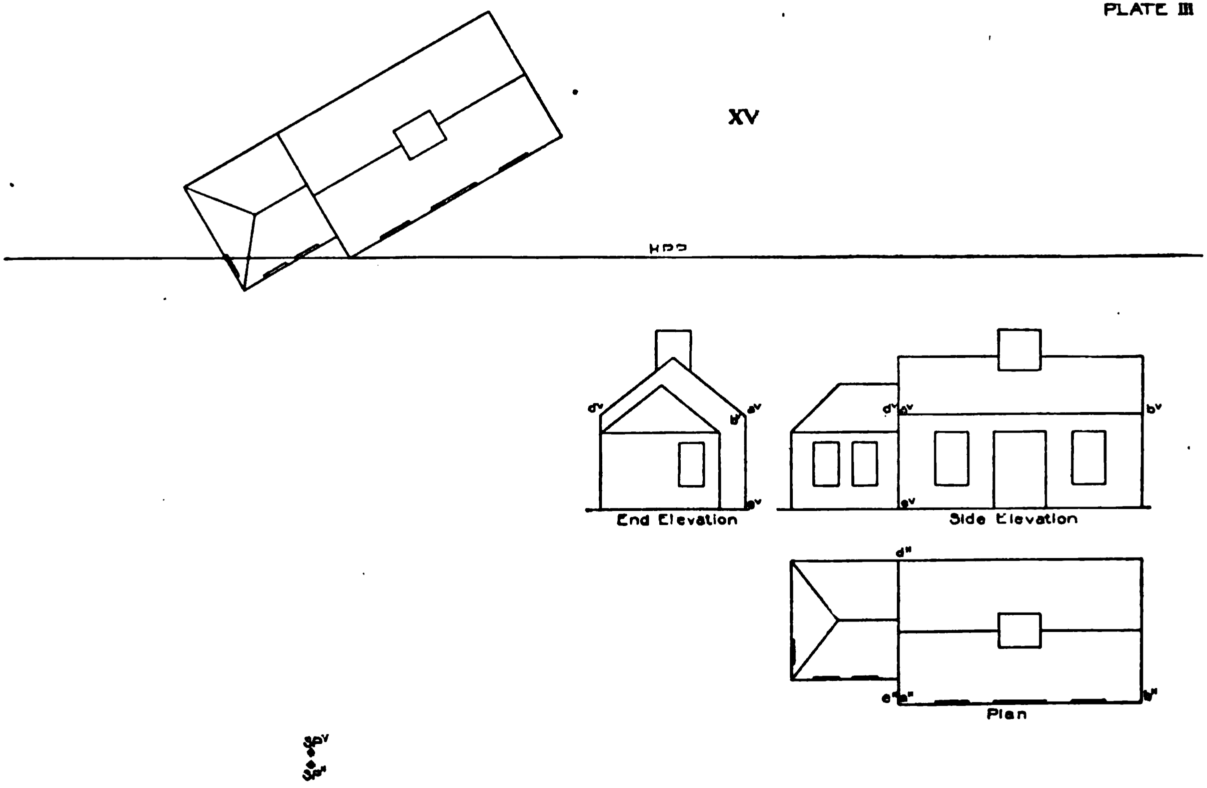

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PLATE IV.

PROBLEM XVI.

The plate shows the plan, front, and side elevations of a house. In order to assist the student in understanding these drawings, an oblique projection (at one-half scale) is given, with the visible lines and planes lettered to agree with those in the plan and elevations.

The problem is, first, to find a complete Vanishing Point Diagram (§ 75) for the house in the position indicated by the given diagram; second, to draw the perspective projection of the house, resting on a horizontal plane six inches below the level of the observer's eye. The projections of the station point are given.

There will be, including the vertical system, eleven systems of lines and eight systems of planes in the vanishing point diagram.

NOTE. — The lines of these systems can most easily be identified by first finding their horizontal projections on the plan.

In finding the vanishing points for the different systems, the student should proceed in the following order: —

1st. Draw VH the vanishing trace for all horizontal planes.

2d. Find v^{ab}, the vanishing point for all horizontal lines in the house that vanish to the right.

3d. Find v^{ad}, the vanishing point for all horizontal lines vanishing to the left.

4th. Find v^{on}. The line *on* forms the intersection of the planes N_1 and U_1 (see oblique projection). To this same system belong the lines *rq*, *ts*, and *zy*.

5th. Find v^{nm}. The line *nm* forms the intersection of the planes M_1 and U_1 (see oblique projection). To this same system belong the lines *qp*, *vu*, and *xw*.

6th. Find v^{fl}. The line *fl* forms the intersection of the planes S and V_1. The line *jk* also belongs to this same system.

7th. Find v^{lg}. The line *ly* forms the intersection of the planes R and V_1. The line *kh* also belongs to this system.

8th. Find v^{dj}. The line dj forms the intersection of the planes P and M. To this same system belongs the line which forms the intersection of the planes P and M_1

9th. Find v^{gb}. The line gb forms the intersection of the planes N and O. To this same system belongs the line which forms the intersection between the planes N_1 and O.

10th. Draw the vanishing traces of the planes M, N, O, P, R, S, U, and V, checking the construction of the vanishing points already found.

11th. v^{af} will now be determined by the intersection of TP and TN (§ 74). The lines forming the intersection of the plane P with the planes N and N_1 will vanish at v^{af}.

In a similar manner v^{hc} will be determined by the intersection of TM and TO. The lines forming the intersections of the plane O with the planes M and M_1 will vanish at v^{hc}.

The complete vanishing point diagram has now been found; and it remains only to establish VH_1 in accordance with the given data, and construct the perspective projection of the house. A bird's-eye view has been chosen for the perspective projection in order to show as many of the roof lines as possible.

Each visible line in the perspective projection should be continued by a dotted construction line, to meet its particular vanishing point.

This problem will require more care in draughting than any of the previous ones, and the angles of the lines in revolved plan and elevation should be laid off with great precision. The student should not attempt to make the perspective projection until the vanishing point diagram is drawn with accuracy.

PLATE V.

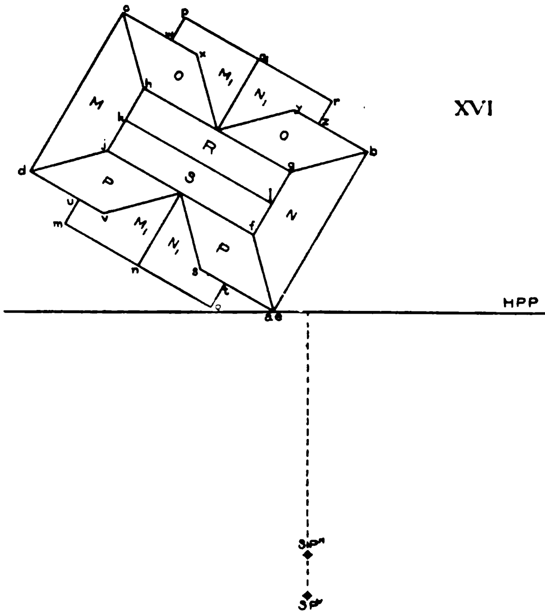
PROBLEM XVII.

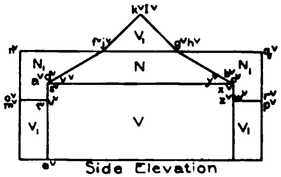
From the given data construct a perspective projection, using the plan of view for a diagram as indicated. HPP, VH_1, SP^V, and SP^H are given.

This plate need not be lettered, except as the student may find it an aid in construction.

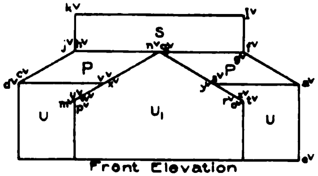
PLATE IV

XVI

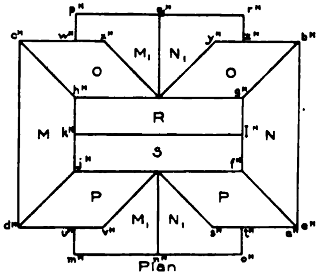




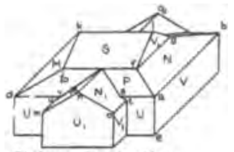
Side Elevation



Front Elevation



Plan



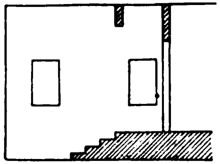
Oblique Projection
at ½ Scale

DATE

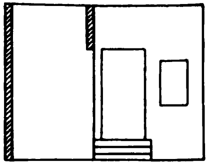
NAME

PLATE V

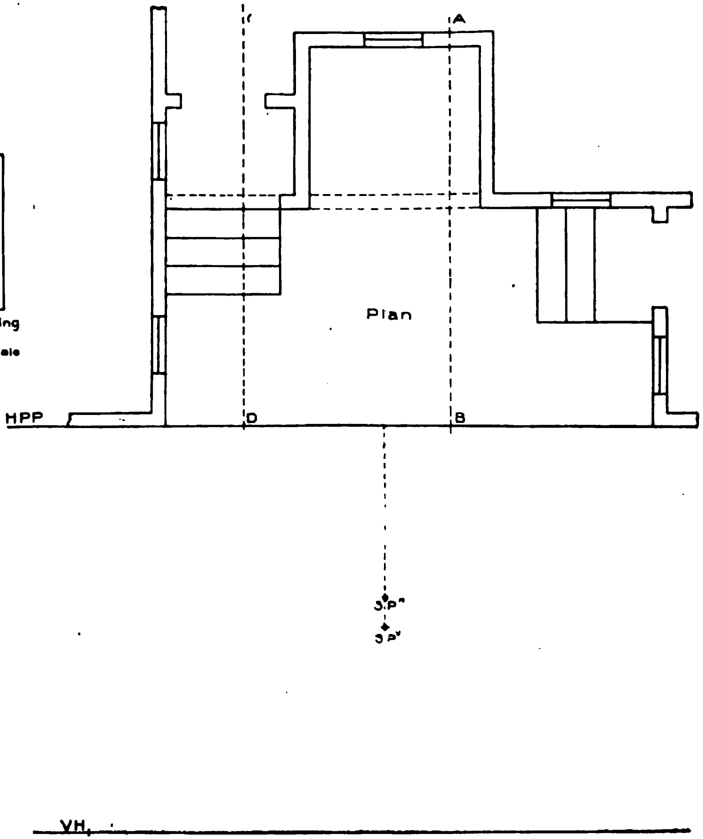
XVII

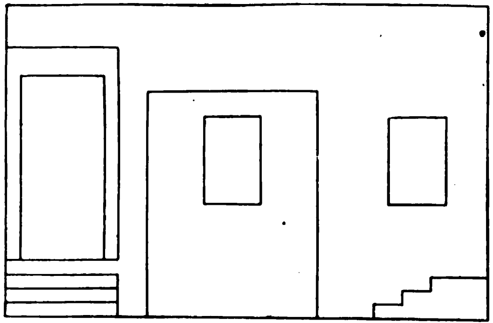


Section on line C D showing left hand side of room.
½ Scale.



Section on line A B showing right hand side of room.
½ Scale





Elevation

DATE

NAME

PLATE VI.

PROBLEM XVIII.

Construct, by the method of perspective plan, a perspective projection of the object shown in the given plan and elevations.

HPP and VH are to be taken coincident (§ 107), as indicated on the plate.

The vanishing points (v^{ab} and v^{ad}) for the two systems of horizontal lines in the object are given. The line *ab* is to make an angle of 60° with the picture plane.

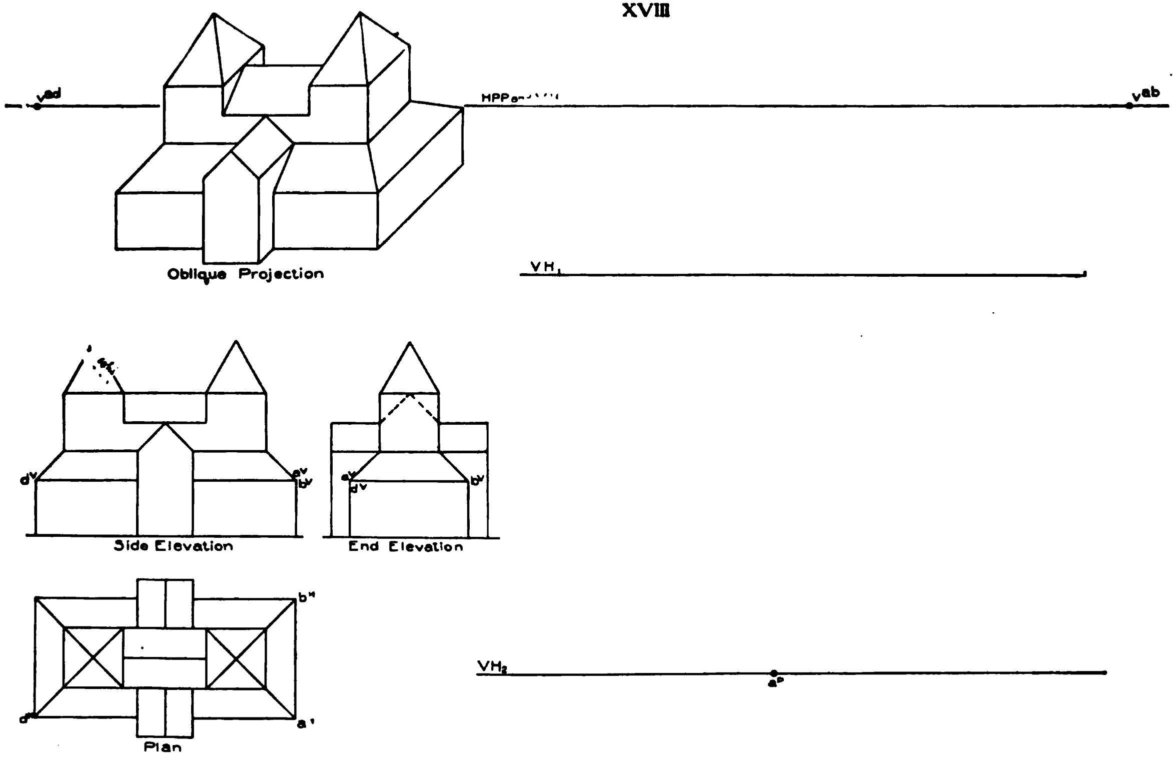
VH_2 is the vertical trace of the horizontal plane on which the perspective plan is to be drawn. The corner (a^P) of this plan is given. The perspective projection of the object is to rest on the horizontal plane determined by VH_1.

An oblique projection of the object is given to assist in reading the plan and elevations.

The student may use his discretion in lettering this plate. No letters are required except those indicating the positions of the station point and the measure points.

PLATE VI

XVIII



Oblique Projection

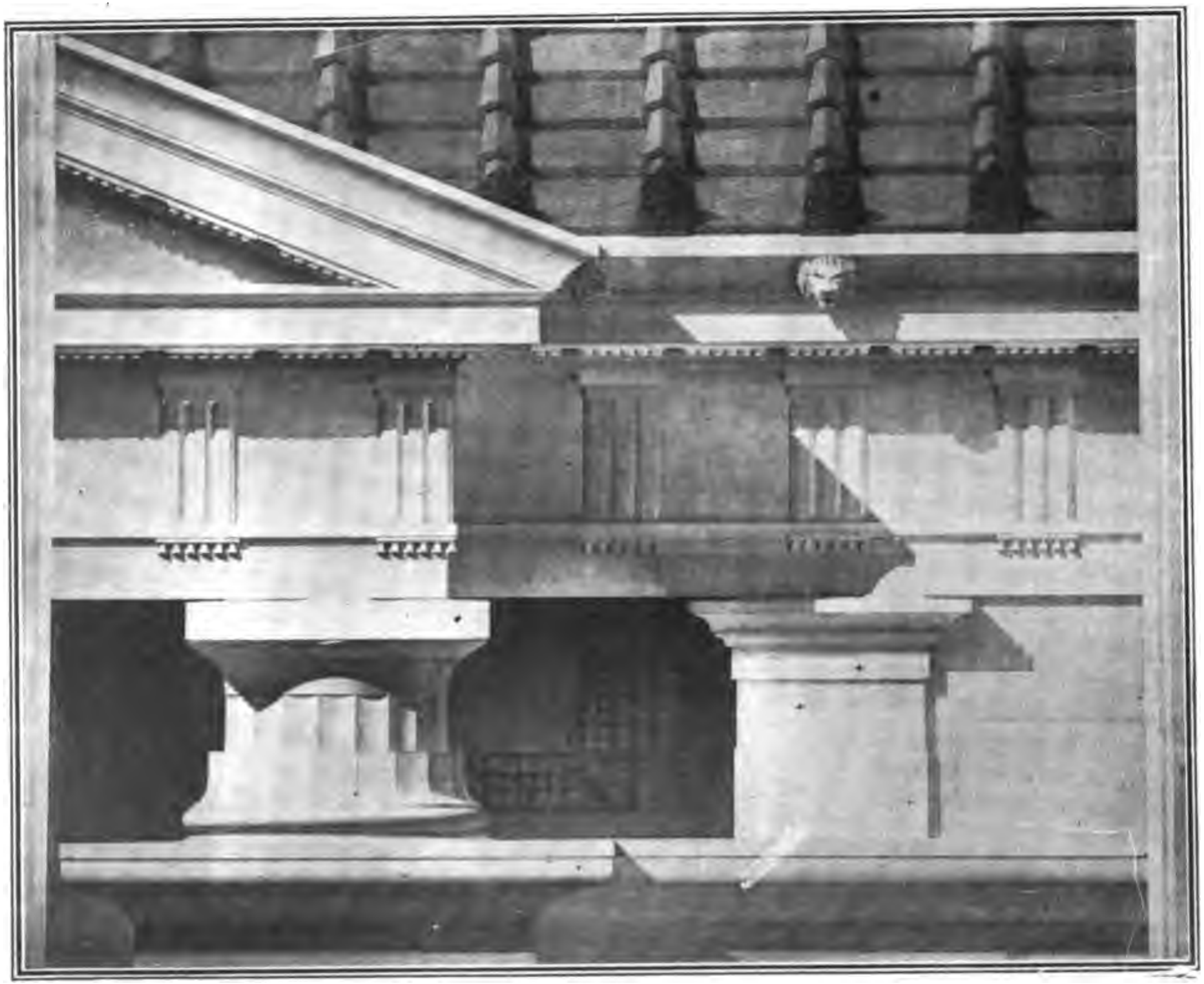
Side Elevation

End Elevation

Plan

DATE

NAME



DETAIL OF GREEK DORIC ORDER.

An example of conventional shadows and rendering.

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SHADES AND SHADOWS.

1. The drawings of which an architect makes use can be divided into two general kinds: those for designing the building and illustrating to the client its scheme and appearance; and "working drawings" which, as their name implies, are the drawings from which the building is erected. The first class includes "studies," "preliminary sketches," and "rendered drawings." Working drawings consist of dimensioned drawings at various scales, and full-sized details.

2. It is in the drawings of the first kind that "shades and shadows" are employed, their use being an aid to a more truthful and realistic representation of the building or object illustrated. All architectural drawings are conventional; that is to say, they are made according to certain rules, but are not pictures in the sense that a painter represents a building. The source of light casting the shadows in an architectural representation of a building is supposed to be, as in the "picture" of a building, the sun, but the direction of its rays is fixed and the laws of light observed in nature are also somewhat modified. The purpose of the architect's drawing is to explain the building, therefore the laws of light in nature are followed only to the extent in which they help this explanation, and are, therefore, not necessarily to be followed consistently or completely. The fixed direction of the sun's rays is a further aid to the purpose of an architectural drawing in that it gives all the drawings a certain uniformity.

3. **Definitions.** A clear understanding of the following terms is necessary to insure an understanding of the explanations which follow.

4. *Shade:* When a body is subjected to rays of light, that portion which is turned away from the source of light and which, therefore, does not receive any of the rays, is said to be in shade. See Fig. 1.

5. *Shadow:* When a surface is in light and an object is

placed between it and the source of light, intercepting thereby some of the rays, that portion of the surface from which light is thus excluded is said to be in shadow.

6. In actual practice distinction is seldom made between these terms "shade" and "shadow," and "shadow" is generally used for that part of an object from which light is excluded.

7. *Umbra:* That portion of space from which light is excluded is called the umbra or invisible shadow.

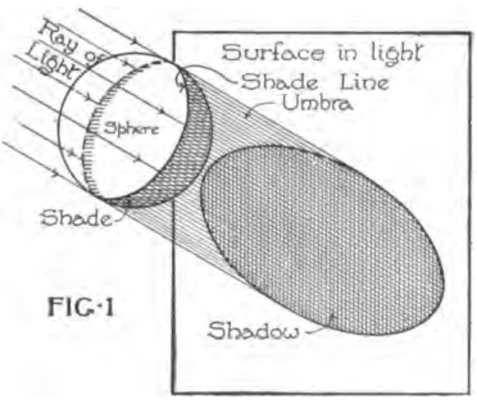
(a) The umbra of a point in space is evidently a line.

(b) The umbra of a line is in general a plane.

(c) The umbra of a plane is in general a solid.

(d) It is also evident, from Fig. 1, that the shadow of an object upon another object is the intersection of the umbra of the first object with the surface of the second object. For example, in Fig. 1, the shadow of the given sphere on the surface in light is the intersection of its umbra (in this case a cylinder) with the given surface producing an ellipse as the shadow of the sphere.

8. *Ray of light:* The sun is the supposed source of light in "shades and shadows," and the rays are propogated from it in straight lines and in all directions. Therefore, the ray of light can be represented graphically by a straight line. Since the sun is at an infinite distance, it can be safely assumed that the rays of light are all parallel.



FIG·1

9. *Plane of light:* A plane of light is any plane containing a ray of light, that is, in the sense of the ray lying in the plane.

10. *Shade line:* The line of separation between the portion of an object in light and the portion in shade is called the shade line.

11. It is evident, from Fig. 1, that this shade line is the boundary of the shade. It is made up of the points of tangency of rays of light tangent to the object.

12. It is also evident that the shadow of the object is the space enclosed by the shadow of the shade line. In Fig. 1, the

shade line of the given sphere is a great circle of the sphere. The shadow of this great circle on the given plane is an ellipse. The portion within the ellipse is the shadow of the sphere.

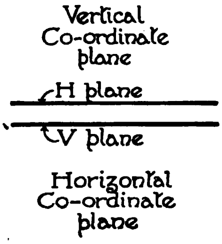
NOTATION.

13. In the following explanations the notation usual in orthographic projections will be followed:

H = horizontal co-ordinate plane.
V = vertical co-ordinate plane.
a = point in space.
a^v = vertical projection (or elevation) of the point.
a^h = horizontal projection (or plan) of the point.
a^{vs} = shadow on V of the point a.
a^{hs} = shadow on H of the point a.
R = ray of light in space.
R^v = vertical projection (or elevation) of ray of light.
R^h = horizontal projection (or plan) of ray of light.
GL= ground line, refers to a plane on which a shadow is to be cast, and *is that projection of the plane which is a line.*

14. In orthographic projection a given point is determined by "projecting" it upon a vertical and upon a horizontal plane. In representing these planes upon a sheet of drawing paper it is evident, since they are at right angles to each other, that when the plane of the paper represents V (the vertical "co-ordinate" plane), the horizontal "co-ordinate" plane H, would be seen and represented as a horizontal line, Fig. 2. *Vice versa*, when the plane of the paper represents H (the horizontal co-ordinate plane), the vertical co-ordinate plane V, would be seen and represented by a horizontal line, Fig. 2.

FIG. 2



15. In architectural drawings having the elevation and plans upon the same sheet, it is customary to place the "elevation," or vertical projection, above the plan, as in Fig. 2.

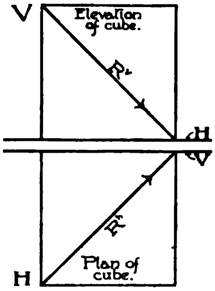
It is evident that the distance between the two ground lines can be that which best suits convenience.

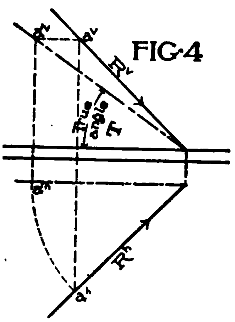
16. As the problems of finding the shades and shadows of objects are problems dealing with points, lines, surfaces, and solids, they are dealt with as problems in Descriptive Geometry. It is assumed that the student is familiar with the principles of orthographic projection. In the following problems, the objects are referred to the usual co-ordinate planes, but as it is unusual in architectural drawings to have the plan and elevation on the same sheet, two ground lines are used instead of one.

17. **Ray of Light.** The assumed direction of the conventional ray of light R, is that of the diagonal of a cube, sloping downward, forward and to the right; the cube being placed so

that its faces are either parallel or perpendicular to H and V. Fig. 3 shows the elevation and plan of such a cube and its diagonal. It will be seen from this that *the H and V projections of the ray of light make angles of 45° with the ground lines. The true angle* which the actual ray in space makes with the co-ordinate planes is 35° 15′ 52′ This true angle can be determined as shown in Fig. 4. Revolve the ray parallel to either of the co-ordinate planes. In Fig. 4, it has been revolved parallel to V, hence T is its true angle.

FIG·3




FIG·4

18. It is important in the following explanations to realize the difference in the terms "ray of light," and "projections of the ray of light."

SHADOWS OF POINTS.

19. **Problem I. To find the shadow of a given point on a given plane.**

Fig. 5 shows the plan and elevation of a given point *a*. It is required to find its shadow on a given plane, in this case the V plane. The shadow of the point *a* on V will be the point at which the ray of light passing through *a* intersects V.

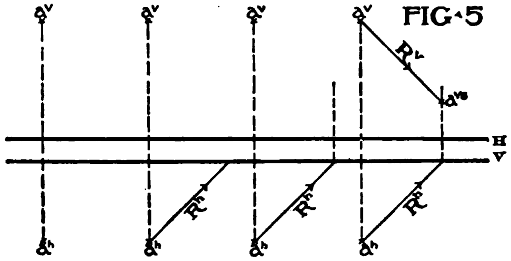
Through the H projection a^h, of the given point, draw R^h until it intersects the lower ground line. This means that the ray of light through *a* has pierced V at some point. The exact point will be on the perpendicular to the ground line, where R^v drawn through a^v intersects the perpendicular. The point a^{vs} is, therefore, the shadow of *a* on the V plane.

R^v is also the V projection of the *umbra* of the point *a* and it will be seen that the shadow of *a* on V is the intersection of its umbra with V.

20. Fig. 6 shows the construction for finding the shadow of a point a on H.

21. Fig. 7 shows the construction for finding the shadow of a point a, which is at an equal distance from both V and H. Its shadow, therefore, falls on the line of intersection of V and H.

22. Fig. 8 shows the construction for finding the imaginary shadow of the point a, situated as in Fig. 5, that is, nearer the V plane than the H. The actual shadow would in this case fall on V, but it is sometimes necessary to find its imaginary shadow on H. The method of determining this is similar to that explained in connection with Fig. 5.

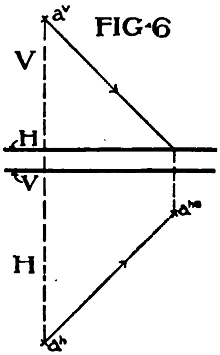

FIG·5

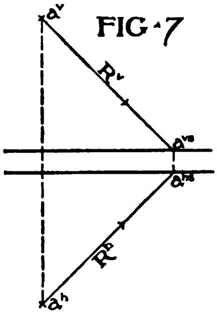
Draw R^v until it meets the ground line of H.

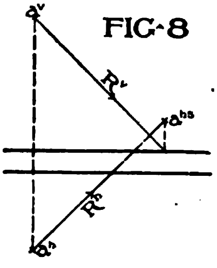
Erect a perpendicular at this point of intersection.

Draw R^h.

The intersection a^{hs}, of the latter and the perpendicular, is the required imaginary shadow on H of the point a.


FIG·6


FIG·7

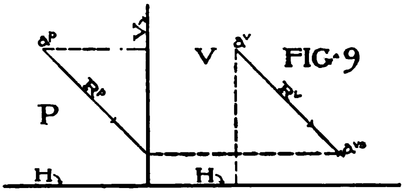

FIG·8

23. The actual shadow of a given point, with reference to the two co-ordinate planes, will fall on the nearer co-ordinate plane.

24. Fig. 9 shows the construction for finding the shadow of

a given point *a* on the V plane when the vertical and profile projections of the point are given.

25. In general, *the finding of the shadow of a given point on a given plane is the same as the finding of the point of intersection of its umbra with that plane.* To obtain this, *one projection of the given plane must be a line and that is used as the ground line.* It is necessary to have a ground line to which is drawn the projection of the ray of light, in order that we may know that the ray of light has pierced the given plane.



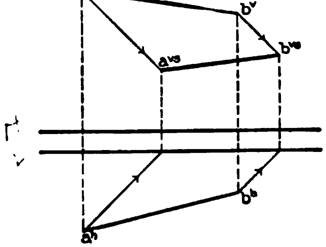
FIG·9

SHADOWS OF LINES.

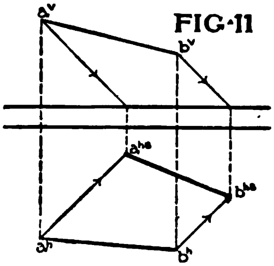
26. **Problem II. To find the shadow of a given line on a given plane.**

A straight line is made up of a series of points. Rays of light passing through all of these points would form a plane of light. The intersection of this plane of light with either of the co-ordinate planes would be the shadow of the given line on that plane. This shadow would be a straight line because two planes always intersect in a straight line. This fact, and the fact that a straight line is determined by two points, enables us to cast the shadow of a given line by simply casting the shadows of any two points in the line and drawing a straight line between these points of shadow.

FIG·10



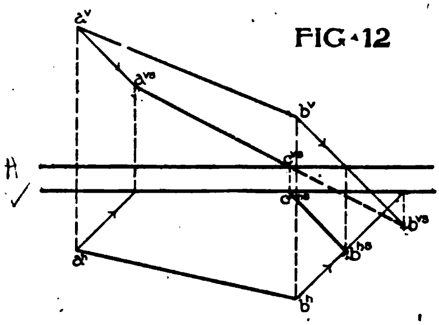
FIG·11

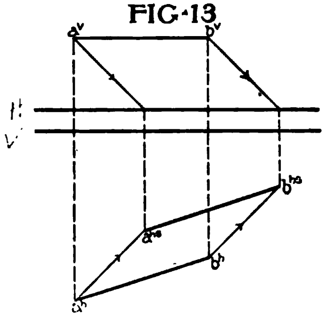


In Fig. 10, a^vb^v and a^hb^h are the elevation and plan respectively of a given line *ab* in space. Casting the shadow of the ends of the line *a* and *b* by the method illustrated in Problem 1 and drawing the line $a^{vs}b^{vs}$, we obtain the shadow of the given line *ab* on V.

27. Fig. 11 shows the construction for finding the shadow of the line *ab* when the shadow falls upon H.

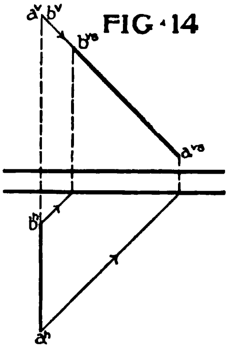
28. Fig. 12 shows the construction for finding the shadow of a line so situated that part of the shadow falls upon V and the remainder on H. To obtain the shadow in such a case, it must be found *wholly on either one of the co-ordinate planes.* In Fig. 12, it has been found wholly on V, a^{vs} being the actual shadow of that end of the line, and b^{vs} being the imaginary shadow of the end b on V. Of the line $a^{vs}b^{vs}$ we use only the part $a^{vs}c^{vs}$, that being the shadow which actually falls upon V.


FIG·12


FIG·13

The point where the shadow leaves V and the point where it begins on H are identical, so that the beginning of the shadow on H will be on the lower ground line directly below the point c^{vs}; c^{hs} will then be one point in the shadow of the line on H, and casting the shadow of the end b we obtain b^{hs}. The line $c^{hs}b^{hs}$, drawn between these points, is evidently the required shadow on H.

29. Another method of casting the shadow of such a line as ab is to determine the entire shadow on each plane independently. This will cause the two shadows to cross the ground lines at the same point c, and of these two lines of shadows we take only the actual shadows as the required result. This method involves unnecessary construction, but should be understood.


FIG·14

30. Fig. 13 shows the construction of the shadow of a given line on a plane to which it is parallel. It should be noted that *the shadow in this case is parallel and equal in length to the given line.*

31. Fig. 14 shows the construction of the shadow of a given line on a plane to which the given line is perpendicular. It is to

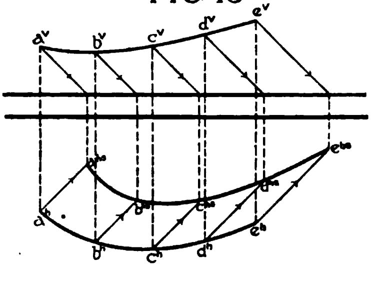
be noted that *the shadow coincides in direction with the projection of the ray of light on that plane*, and is equal in length to the diagonal of a square of which the given line is one side.

32. Fig. 15 shows the construction for finding the shadow of a curved line on a given plane. Under these conditions we find, by Problem 1, the shadows of a number of points in the line—the greater the number of points taken the more accurate the resulting shadow. The curve drawn through these points of shadow is the required shadow.

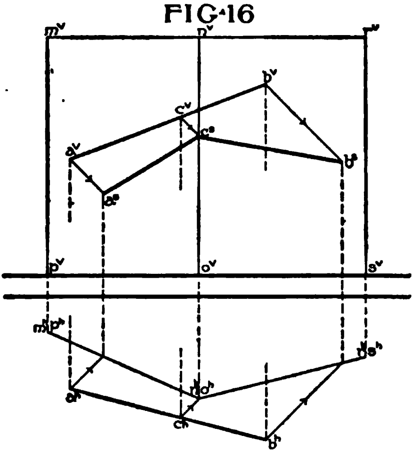
33. In Fig. 16 the given line *ab* is in space and the problem is to find its shadow on two rectangular planes *mnop* and *nrso*, both perpendicular to H.

Consider first the shadow of *ab* on the plane *mnop*. The edge *no* is the limit of this plane on the right. Therefore from the point n^h draw back to the given line the projection of a ray of light. This 45° line intersects the given line at c^h. It is evident that of the given line

FIG·15



FIG·16

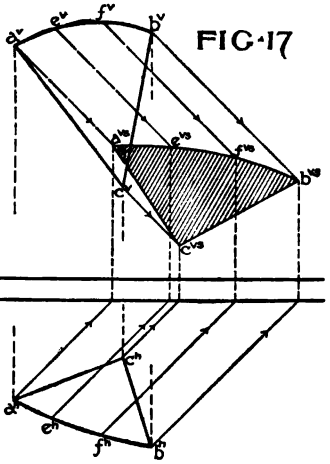


ab, the part *ac* falls on the plane *mnop* and the remainder, *cb*, on the plane *nrso*.

To find the shadow of *ac* on the left-hand plane we must first determine our ground line. *The ground line will be that projection of the plane receiving the shadow which is a line.* In this example the vertical projection of the plane *mnop* is the rectangle $m^vn^vo^vp^v$. This projection cannot, therefore, be used as a GL. The plan, or H projection, of this plane is, however, a line m^hn^h. This line, therefore, will be used as the ground line for finding the shadow of *ac* on *mnop*.

We find the shadow of a to be at a^s and the shadow of c at c^s, Problem I. The line a^sc^s is, therefore, a part of the required shadow. The remaining part, c^sb^s is found in a similar manner.

34. The above illustrates the method of determining the GL when the shadow falls upon some plane other than a co-ordinate plane. In case neither projection of the given plane is a line, the shadow must be determined by methods which will be explained later.



FIG·17

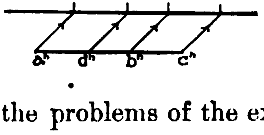
SHADOWS OF PLANES.

35. **Problem III. To find the shadow of a given plane on a given plane.**

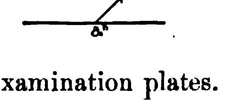
Plane surfaces are bounded by straight or curved lines. Find the shadows of the bounding lines by the method shown in Problem II. The resulting figure will be the required shadow.

36. In Fig. 17, the plane abc is so situated that its shadow falls wholly upon V. The shadows of its bounding lines, ab, bc, ca have been found by Problem II.

FIG·18



FIG·19



That portion of the shadow hidden by the plane in elevation is cross-hatched along the edge of the shadow only. This method of indicating actual shadows which are hidden by the object is to be followed in working out the problems of the examination plates.

37. Fig. 18 shows the construction of the shadow of a plane on the co-ordinate plane to which the given plane is parallel. (In this case the vertical plane.) It is to be observed that *the shadow is equal in size and shape to the given plane.*

Fig. 19 shows that, in case of a circle parallel to one of the co-ordinate planes, it is only necessary to find the shadow of the center of the circle and with that point as a center construct a circle of the same radius as that of the given circle.

NOTE:

39. Any point, line, or plane lying in a surface is considered to be its own shadow on that surface.

40. A *surface parallel to a ray of light is considered to be in* shade.

41. In the above problems the points, lines and planes have been given in vertical and horizontal projection. The methods for finding their shadows are, in general, equally true when the points, lines and planes are given by vertical and profile projection or horizontal and profile projection.

SHADOWS OF SOLIDS.

42. The methods for finding the shadows of solids vary with the nature of the given solid. The shadows of solids which are bounded by plane surfaces, none of which are parallel, or perpendicular, to the co-ordinate planes, can in general, be found only by finding the shadows of all the bounding planes. These will form an enclosed polygon, the sides of which are the shadows of the shade lines of the object, and the shade lines of the solid are determined in this way. The following is an illustration of this class of solids.

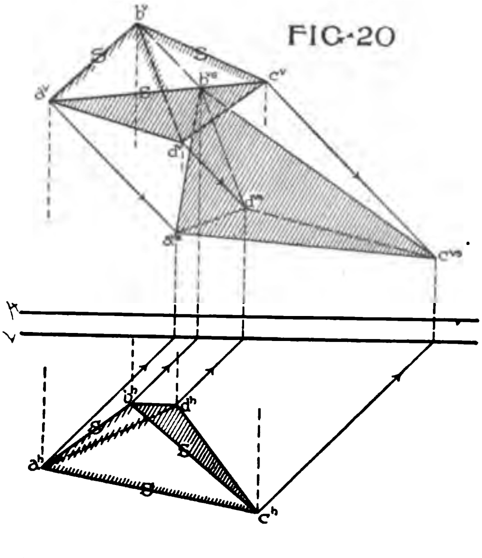


FIG-20

43. **Problem IV. To find the shade and shadow of a polyhedron, none of whose faces are parallel or perpendicular to the co-ordinate planes.**

Fig 20 shows a polyhedron in such a position and of such a shape that none of its faces are perpendicular or parallel to the co-ordinate planes. It is impossible, therefore, to apply to this figure the projections of the rays of light and determine what faces are in light and what in shade. Consequently we cannot determine the shade line whose shadows would form the shadow of the object.

Under these circumstances we must cast the shadows of all the boundary edges of the object. Some of these lines of shadow will form a polygon, the others will fall inside this polygon. The edges of the object whose shadows form the bounding lines of the polygon of shadow are the shade lines of the given object. Knowing the shade lines, the light and shaded portions of the object can now be determined, since these are separated by the shade lines.

In a problem of this kind care should be taken to letter or number the edges of the given object.

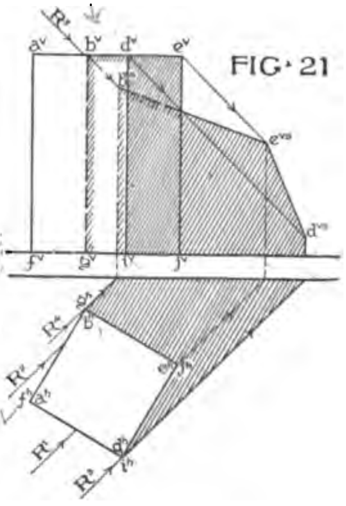
44. The edges of the polyhedron shown in Fig. 20 are *ab*, *bc*, *cd*, *da*, *ac* and *bd*.

Cast the shadows of each of these straight lines by the method shown in Problem II.

We thus obtain a polygon bounded by the lines $b^{vs}c^{vs}$, $c^{vs}a^{vs}$, $a^{vs}b^{vs}$, and this polygon is the shadow of the given solid.

The lines which cast these lines of shadow, $b^{vs}c^{vs}$, $c^{vs}a^{vs}$, and $a^{vs}b^{vs}$ are therefore the shade lines of the object, and, therefore, the face *abc* is in light and the faces *abd*, *bcd* and *acd* are in shade.

The shadows of the edges *bd*, *dc*, and *ad* falling within the polygon, indicate that they are not shade lines of the given object, and, therefore, they separate two faces in shade or two faces in light. In this example *bd* and *cd* separate two dark faces.


FIG·21

In architectural drawings the object usually has a sufficient number of its planes perpendicular or parallel to the co-ordinate planes, to permit its shadow being found by a simpler and more direct method than the one just explained.

45. **Problem V. To find the shade and shadow of a prism on the co-ordinate planes, the faces of the prism being perpendicular or parallel to the V and H planes.**

In Fig. 21 such a prism is shown in plan and elevation. The elevation shows it to be resting on H, and the plan shows it to be situated in front of V, its sides making angles with V. Since its top and bottom faces are parallel to H and its side faces perpendicular to that plane, we can apply the projections of the rays of light to the plan and determine at once which of the side faces are in light and which in shade. The projections of the rays R^1 and R^2 show that the faces *abgf* and *adif* receive the light directly, and that the two other side faces do not receive the rays of light and are, therefore, in shade. The edges *bg* and *di* are two of the shade lines. R^3 and R^4 are the projections of the rays which are tangent to the prism along these shade lines.

Applying the projection R^5 in the elevation makes it evident that the top face of the prism is in light and the bottom face is in shade since the prism rests on H. This determines the light and shade of all the faces of the prism, and the other shade lines would therefore be *be* and *ed*.

Casting the shadow of each of these shade lines, we obtain the required shadow on V and H.

It is evident that the shadows of the edges *bg* and *di* on H will be 45° lines since these edges are perpendicular to H (§ 31) Also, their shadows on V will be parallel to the lines themselves since these shade lines are parallel to V. (§ 30)

46. In general, to find the shadow of an object whose planes are parallel or perpendicular to H or V:

(1) Apply to the object the projections of the ray of light to determine the lighted and shaded faces.

(2) These determine the shade lines.

(3) Cast the shadows of these shade lines by the method followed in Problem II.

47. **Problem VI. To find the shade and shadow of one object on another.**

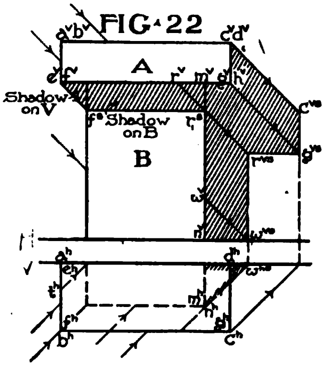
In Fig. 22 is shown in plan and elevation a prism B, resting on H and against V. Upon this prism rests a plinth A: To find the shadow of the plinth on the prism and the shadow of both on the co-ordinate planes. Since these objects have their faces either perpendicular to, or parallel to, the co-ordinate planes, we can determine immediately the light and shade faces and from them the shade lines.

48. Considering first the plinth A, it is evident that its top, left-hand and front faces will receive the light, that the lower and right-hand faces will be in shade. The back face resting against the V plane will be its own shadow on V. (§ 39) The shade lines of A will be, therefore, *ef*, *fg*, *gc* and *cd*.

Cast the shadows of these lines. A rests against V and part of its shadow will fall on V; also, since it rests on B the remainder will fall on B. Begin with the point *e*, one end of the shade line; this point, lying in V, is its own shadow on V. (§ 39).

The line *ef* being perpendicular to V, its shadow, or as much of its shadow as falls on V, will be, therefore, a 45° line drawn from e^v. The point t^h, in plan, shows the amount of the line *ef* which falls on V, the rest *tf* falls on the side face of the prism, and this shadow is not visible in elevation or plan.

The shadow of the point *f* evidently falls on the edge of the prism at f^s, see plan. This point *f* is one end of the shade line *fg*, therefore *f* is one point in the shadow of *fg* on the front face of the prism B. The line *fg* being parallel to this front face, its shadow will be parallel to the line, therefore from the point f^s we draw the horizontal line $f^s r_1^s$.



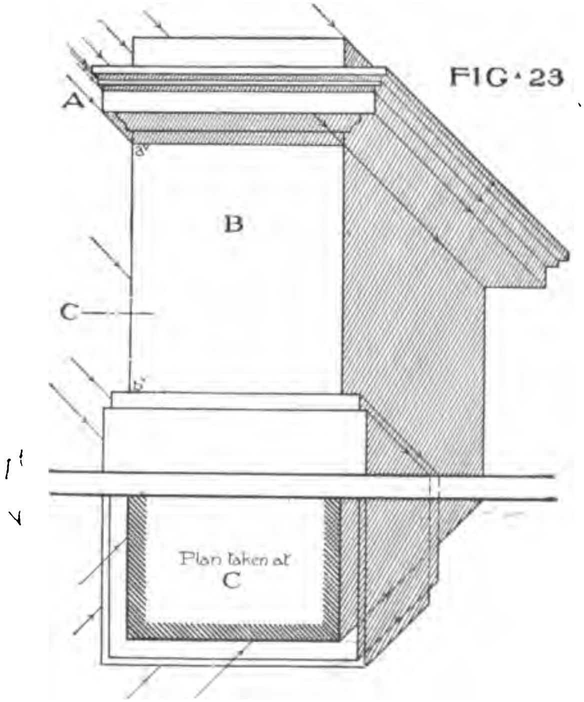
If from the point r_1^s we draw the projection of a ray of light back to the shade line $f^v g^v$ we determine the amount of the line casting a shadow on the front face of B, that is to say, the distance $f^v r^v$. The shadow of the remainder, $r^v g^v$, falls beyond the prism on the V plane, and is evidently the line $r^{vs} g^{vs}$. Thus the shadow of the shade line from *e* to *g* has been determined.

The next portion of the shade line, *gc*, is a vertical line and we have already obtained the shadow of the end *g*. Since it is a vertical line its shadow on V will be vertical and equal in length. Therefore draw $g^{vs} c^{vs}$.

There remains now only the edge, *cd*, of which to cast the shadow. The end *d* being in the V plane must be its own shadow on that plane. (§ 39) We have already found the shadow of the other end c, at c^{vs}. Therefore $d^v c^{vs}$ is the shadow of dc and completes the outline of the shadow of the plinth.

It will be noted that $d^v c^{vs}$ is a 45° line, which would be expected since the edge dc is perpendicular to V.

49. Considering next the prism B, we find by applying the projections of the rays of light to the plan, that the front and left-hand faces are in light, and that the right-hand face is in shade. Therefore the only shade line in this case is the edge mn. The upper part of this, $m^v r_1^s$ is in the shade of the plinth and therefore cannot cast any shadow.



FIG·23

It is to be noted that the ray of light from the point r^v in the plinth A passes through the point r_1^s in the shade line of the prism B. In finding the shadow of this point at r^{vs} we therefore have found the shadow also of one end of the shade line nr. Since nr is vertical, its shadow will be vertical on V. Therefore draw $r^{vs} n^{vs}$. This line completes the shadow of the two objects upon the V plane.

From the point of shadow w^{vs} draw the V projection of the ray back to the line $n^v r_1^s$. This shows how much of the total line nr falls upon V, and how much upon H.

The shadow on H of the portion nw will be a 45° line since nw is perpendicular to H. The point n being in the H plane is its own shadow on that plane.

It is to be noted that the point w^{hs} is on the perpendicular directly below w^{vs}.

50. **Problem VII. To find the shade and shadow of a pedestal.**

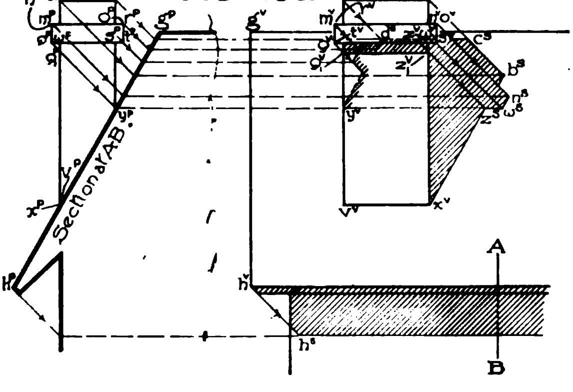
Fig. 23 shows the plan and elevation of a pedestal resting on the ground and against a vertical wall. This is an application of the preceding problem in finding the shades and shadows of one object upon another. The profile of the cornice moulding on the left, at A, can be used as a profile projection in finding the shadows of those mouldings on themselves and upon the front face B, of the pedestal. By drawing the profile projections of the rays tangent to this profile of mouldings, it will be seen what edges are shade lines and where their shadows will fall on the surface of B. The line $a^v b^v$ can be assumed to be the profile projection of the front face of B, and being a line is used as the *ground line* for finding the shadow on B. As this collection of mouldings is parallel to the V plane their shades and shadows will be parallel in the elevation. Otherwise the shadows of this pedestal are found in a manner similar to the preceding problem.

51. **Problem VIII. To find the shadow of a chimney on a sloping roof.**

Fig. 23a shows in elevation and side elevation the chimney and roof. The chimney itself being made up of prisms with their planes parallel or perpendicular to the V plane, its light and shade faces can be determined at once, as in Problem V. It will be evident from the figure that the top, front, and left-hand faces of the chimney in elevation will be in light. The remaining faces will be in shade, and the shade lines will be therefore, yd, on the back, dc, cb, and bx. Not all of bx and yd will cast shadows for the shadow of the flat band, running around the upper part of the chimney, will cause a portion of these two lines yd and bx to be in shadow and such portions cannot cast any shadows. (See Problem VI—the shadow of one object upon another.)

It is evident that, to find the shadow of the shade line of the chimney upon the sloping roof, *we must have for a ground line a projection of the roof which is a line.* The roof in elevation is projected as a plane, but the side elevation (or in other words the profile projection) shows the roof projected as a line in the line $h^p g^p$. This line will be then the ground line for finding the shadow of any point in the chimney on the roof. For example, take the point b. If we draw the profile projection of the ray through the point b^p until it intersects the ground line $h^p g^p$, and draw from this point of intersection a horizontal line across until it intersects the vertical projection of the ray drawn through b^v, this last point of intersection b^s, will be the shadow of b upon the roof. In a similar manner the shadow of any point or line in the chimney can be found on the roof.

FIG·23a



Before completing the shadow of the chimney upon the roof let us consider the shadow of the flat band on the main part of the chimney. This band projects the same amount on all sides. On the left-hand and front faces it will cast a shadow on the chimney proper. Only the shadow on the front face will be visible in elevation. To find this, draw the profile projection of the ray through the point q^p until it intersects the line $a^p v^p$, the profile projection of the front face. From this point $q_1{}^p$ draw a horizontal line across until it meets the vertical projection of the ray drawn through q^v. From q^v, the shadow of $q^v w^v$ on the front face will be parallel to $q^v w^v$, for that line is parallel to that face; therefore draw $q_1{}^v z_1{}^v$.

Now that the visible shadows on the chimney itself have been determined, its shadow on the roof can be found as explained in the first part of this problem. A portion of the shade line of the flat band, z^vw^v, w^vn^v, etc., falls beyond the chimney on the roof, as shown by the line z^sw^s, w^sn^s, etc.

52. It is to be noted in the shadow on the roof that:

(a) The shadows of the vertical edges of the chimney *make angles with a horizontal line equal to the angle of the slope of the roof* (in this case 60°).

(b) The horizontal edges which are parallel to V cast shadows which *are parallel to these same edges* in the chimney.

(c) The horizontal edges which are perpendicular to V cast shadows which *make angles of 45° with a horizontal line.*

53. The above method would also be used in finding shadows on sloping surfaces when the objects are given in elevation and side elevation, as, for example, a dormer window.

54. **Problem IX. To find the shades and shadows of a hand rail on a flight of steps and on the ground.**

Fig. 24 shows the plan and elevation of a flight of four steps situated in front of a vertical wall, with a solid hand rail on either side, the hand rails being terminated by rectangular posts. At a smaller scale is shown a section through the steps and the slope of the hand rail.

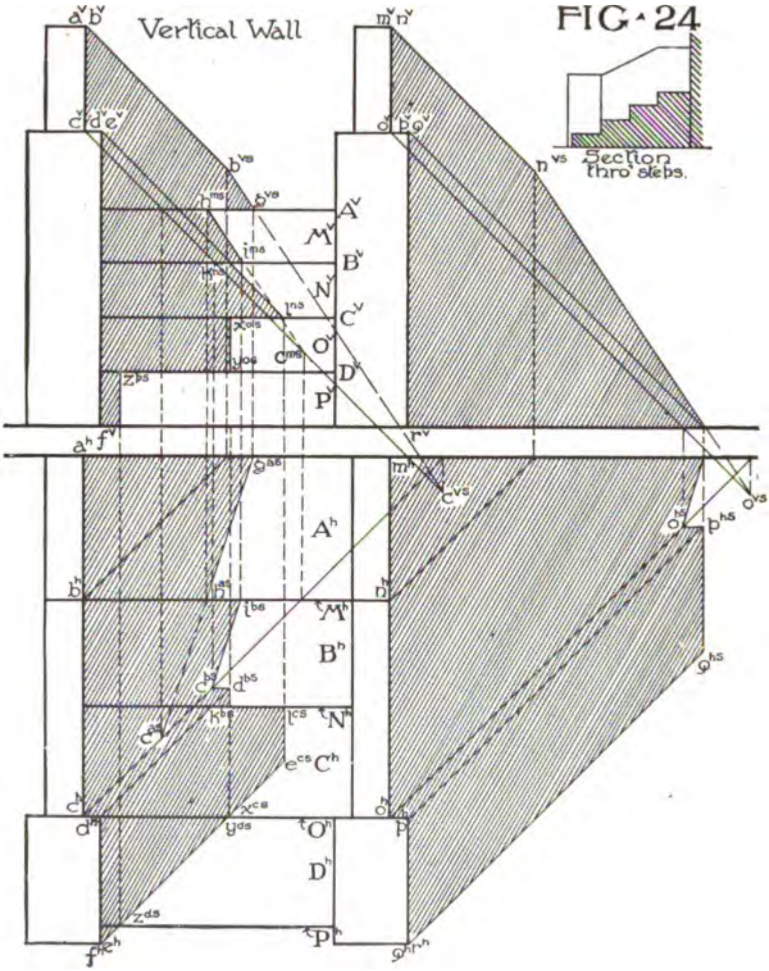
This problem amounts to finding the shadow of a broken line, that is to say, the shade line, on a series of planes. Each of the planes requires its own ground line, which in the case of each plane will be that projection of the plane which is a line. Since the planes of the steps and rails, with one exception, are all parallel or perpendicular to the co-ordinate planes we can determine at once what planes are in light and what in shadow and thus determine the shade line.

55. An inspection of the figure will make it evident that the "treads" of the steps, A, B, C, D and the "risers," M, N, O, P are all in light. Of the hand rail it will be evident also that the left-hand face, the top, and the front face of the post are in light. The remaining faces are in shade. This is true of both rails; therefore, in one case we must find the shadow of a broken line, *abcdef* on the vertical wall and on the steps, and then find the shadow of

the broken line *mnopqr* on the vertical wall and on the ground.

56. Beginning with the shadow of the left-hand rail, the shadow of the point *a* on the wall is evidently a^v, since *a* lies in the plane of the vertical wall (§ 39)

The line *ab* is perpendicular to V hence its shadow will be a 45° line, the point b^{vs} being found by Problem I. The shadow of *bc*, the sloping part of the rail, will fall partly on the vertical wall and partly on the treads and risers. We have already found the shadow of the end *b* on V in the point b^{vs}. The shadow of *c*



on V, found by Problem I will be c^{vs}. The portion $h^{vs}g^{vs}$ is the part of the shadow of this line hc that actually falls on the wall, the steps preventing the rest of the line from falling on V.

The line of shadow now leaves the vertical wall at the point g^{as}, directly below g^{vs}. The *ground line* for finding the shadow on this upper tread will evidently be the line A^v, since *that line is the projection of this tread which is a line.* The horizontal projection of the tread is a plane between the lines a^hm^h and b^hn^h. We have now determined our GL and we also have one point, g^{as} in the required shadow on the upper tread A. It remains to find the shadow of the end c on A. Draw the projection of the ray through c^v until it meets the line A^v, drop a perpendicular until it intersects the projection of the ray drawn through c^h at the point c^{as}. The point c^{as} lies on the plane A extended. Draw the line $g^{as}c^{as}$. The portion $g^{as}h^{as}$ is the part actually falling on the tread A.

From this point h, the shadow leaves tread A and falls on the upper riser M. The shadow will now show in elevation and begin at the point h^{ms} directly above the point h^{as}.

We now determine a new *ground line* and *it will be that projection of the upper riser M, which is a line.* The vertical projection of M is a plane surface between the lines A^v and B^v. The H projection of the riser M is the line M^h, therefore this is our GL, and we find the shadow on M in a manner similar to the finding of the shadow on A, just explained. Bear in mind that we have one point h^{ms}, already found in this required shadow on M.

In a like manner the shadow of the remainder of the shade line is found until the point f is reached, which is its own shadow on the ground. (39)

57. It is to be noted that, since the plane of the vertical wall and the planes of the risers are all parallel, the shadows on these surfaces of the same line are all parallel. For a similar reason, the shadows of the same line on the treads and ground will be parallel. This fact serves as a check as to the correctness of the shadow.

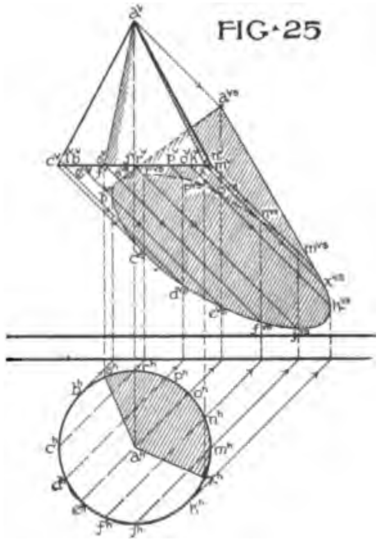
Also note in the plan that the shadow of the vertical edge ef of the post is a continuous 45° line on the ground, the lower tread D, and on the next tread C, above. *While this line of shadow on the object is of course in reality a broken line, it appears in horizontal projection on plan as a continuous line.*

The shadow of the shade line of the right-hand rail is simply the shadow of a broken line on the co-ordinate planes, and requires no detailed explanation.

58. **Problem X. To find the shade and shadow of a cone.**

The finding of the shadow of a cone is, in general, similar to finding the shadow of the polyhedron none of whose planes are perpendicular or parallel to the co-ordinate planes.

It is impossible to determine at the beginning, the shade elements of the cone whose shadows give the shadow of the cone, and we first find the shadow of the cone itself and from that determine its shade elements: that is to say we reverse the usual process in determining the shadow of an object.

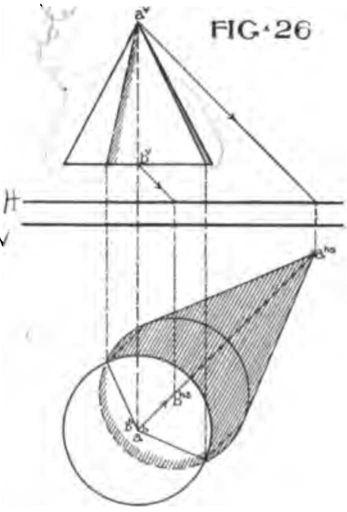

FIG·25

59. Fig. 25 shows, in elevation and plan, a cone whose apex is *a* and whose base is *bcde*, etc. The axis is perpendicular to H and the cone is so situated that its shadow falls entirely on the V plane.

60. It is evident that the shadow of the cone must contain the shadow of its base and also the shadow of its apex. Therefore, if we find the shadow of its apex by Problem I, and then find the shadow of its base by Problem III and draw straight lines from the shadow of the apex tangent to the shadow of the base, the resulting figure will be the required shadow of the cone.

61. This has been done in Fig. 25, in which a^{vs} is the shadow of the apex *a*. The ellipse $b^{vs}c^{vs}d^{vs}$, etc., is the shadow of the base, found by assuming a sufficient number of points in the perimeter of the base and finding their shadows. The ellipse drawn through these points of shadow is evidently the shadow of the base. From the point a^{vs} the straight lines $a^{vs}s^{vs}$ and $a^{vs}x^{vs}$ were drawn tangent to the ellipse of the shadow. This determined the shadow on V of the cone. The lines $a^{vs}s^{vs}$ and $a^{vs}x^{vs}$ are

the shadows of the shade elements of the cone. It remains to determine these in the cone itself. Any point in the perimeter of the shadow of the base must have a corresponding point in the perimeter of the base of the cone, and this can be determined by drawing from the point in the shadow the projection of the ray back to the perimeter of the base. Therefore if we draw 45°-lines from the point x^{vs} and s^{vs} back to the line $c^v m^v$ in the elevation, we determine the points x^v and s^v. The lines drawn from these points to the apex a^v are the shade elements of the cone. They can be determined in plan by projection from the elevation. The cross-hatched portion of the cone indicates its shade. It will be observed that but little of it is visible in elevation.



FIG·26

62. When the plane of the base of the cone is parallel to the plane on which the shadow falls, as in Fig. 26, the work of finding its shade and shadow is materially reduced, for the shadow of the base can then be found by finding the shadow of the center b of the base and drawing a circle of the same radius. (See Fig. 19)

63. In general, to find the shadow of any cone, find the shadow of its apex, then the shadow of its base, draw straight lines from the former, tangent to the latter. Care should be taken, however, that both the shadow of the apex and the shadow of the base are found on the same plane.

64. It is to be noted that in a cone whose elements make an angle of *35°-15'-52" or less*, that is, making the true angle of the ray of light or less, with the co-ordinate plane, the shadow of the apex will fall within the shadow of the base, and, therefore, the cone will have no shade on its conical surface.

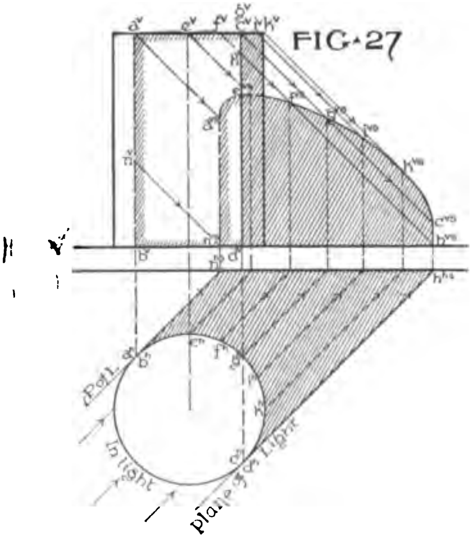
65. **Problem XI. To find the shade and shadow of a right cylinder.**

In Fig. 27 is shown the plan and elevation of a right cylinder resting on H. The rays of light will evidently strike the top of the cylinder and the cylindrical surface shown in the plan between the points b^h and d^h. At these points, the projections of the ray of light are tangent, and these points in plan determine the shade elements of the cylinder in elevation. These shade elements, a^vb^v and c^vd^v, are the lines of tangency of planes of light tangent to the cylinder. The shadow of these lines ab and cd, together with the shadow of the arc $aefg$, etc., of the top of the cylinder, form the complete shadow of the cylinder.

Since ab and cd are perpendicular to H, as much of their shadow as falls upon the H plane will be 45° lines drawn from b^h and d^h respectively. In one case the amount is the line n^vb^v, in the other h^vd^v. The remainder of the lines will fall upon V and this is found by Problem II. These shadows on V will evidently be parallel to a^vn^v and c^vh^v.

The shadow of the shade line $aefg$, etc., on V will be found by Problem II. (§ 32)

66. If the cylinder had been placed so that the whole of its shadow fell upon H, the shadow of the shade line of the top would have been found by finding the shadow of the center of the circle and drawing a circle of the same radius, since the plane of the top is parallel to H. (§ 38)



FIG·27

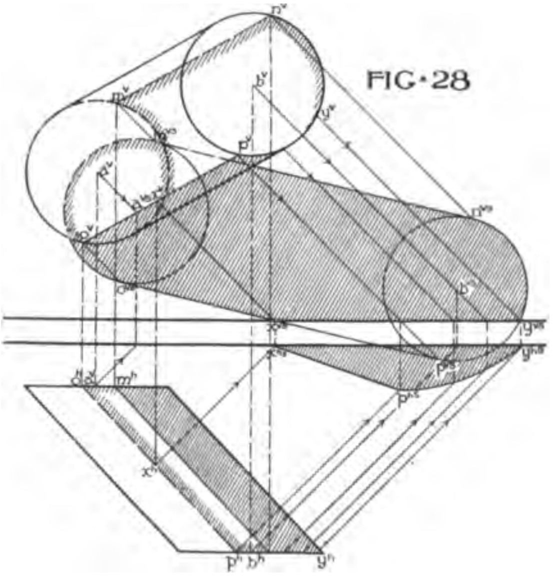
67. **Problem XII. To find the shade and shadow of an oblique cylinder.**

In Fig. 28 is shown the plan and elevation of an oblique cylinder whose vertical section is a circle.

68. Unlike the right cylinder we cannot apply to the plan or elevation the projections of the ray and determine at once the location of the shade elements. To find the shadow of an oblique cylinder we proceed in a manner similar to finding the shade and shadow of a cone; that is, we find first the shadow of the cylinder and from that shadow determine the shade elements.

69. In Fig. 28 the top and base of the oblique cylinder have been assumed, for convenience, parallel to one of the co-ordinate planes. The shadow of the cylinder will contain the shadows of the top and base, hence if we find their shadows and draw straight lines tangent to these shadows, we shall obtain the required shadow of the cylinder.

70. In Fig. 28, the top and bottom being circles, the shadows of their centers a and b are found at a^{vs} and b^{vs}, and circles of the same radius are drawn. Then the lines $m^{vs}n^{vs}$ and $o^{vs}p^{vs}$ are drawn tangent to these circles. The resulting figure is the required shadow wholly on V. Projections of the ray are then drawn back from m^{vs}, n^{vs}, o^{vs} and p^{vs} respectively to the perimeter of the top and base. Their points of intersection m^v, n^v, o^v and p^v are the ends of the shade elements in the elevation. They can be found in plan by projection. An inspection of the figure will make it evident what portions of the cylindrical surface between these shade elements will be light and what in shade.

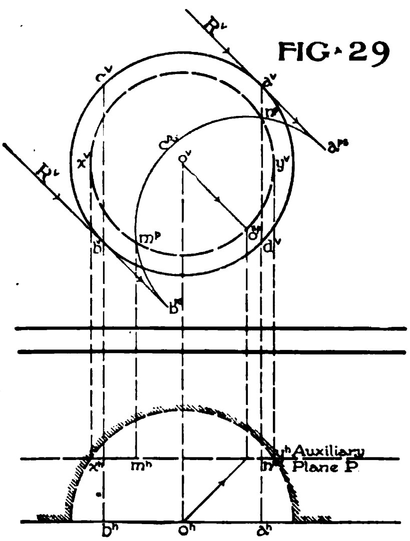

FIG·28

71. In this problem it will be seen that the shadow does not fall wholly upon V. The shadow leaves V at the points x^{vs} and y^{vs} and will evidently begin on H at points directly below, as x^{hs} and y^{hs}.

If projections of the ray are drawn back to the object in plan and elevation from these points, x^{vs}, y^{vs}, x^{hs}, and y^{hs}, they will determine the portion of the shade line which casts its shadow on H. It is evident that in this particular object it is that portion of the shade line of the top between the points p and y and the portion xp, of one of the shade elements. The shadows of these lines are found on H by Problem II.

USE OF AUXILIARY PLANES.

72. In finding shadows on some of the double-curved surfaces of revolution, such as the surface of the spherical hollow, the scotia and the torus, we can make use of auxiliary planes to advantage, *when the plane of the line whose shadow is to be cast is parallel to one of the co-ordinate planes.*


FIG·29

73. **Problem XIII. To find the shadow in a spherical hollow.**

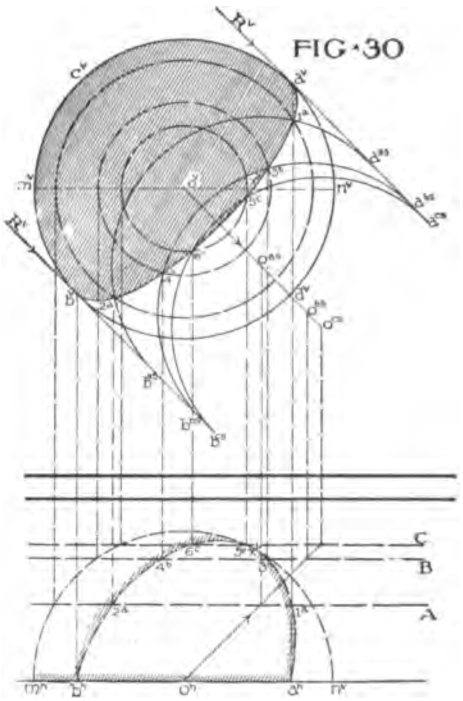
Fig. 29 shows in plan and elevation a spherical hollow whose plane has been assumed parallel to V.

Applying to the elevation, the projections of the ray R, we determine the amount of the edge of the hollow which will cast a shadow on the spherical surface inside. The points of tangency a^v and b^v are the limits of this shade line $a^vc^vb^v$. The remaining portion of the line $a^vd^vb^v$ is not a shade line since the light would reach the spherical surface adjacent to it and also reach the plane surface on the other side of $a^vd^vb^v$ outside the spherical hollow.

We must now cast the shadow of the line $a^vc^vb^v$ on the spherical surface of the hollow, and having no ground line, (since neither the V nor the H projection of the spherical hollow is a line,) we use auxiliary planes.

If we pass through the spherical hollow, parallel to the plane of the line *acb* (in this case parallel to V) an auxiliary plane P, it will cut on the spherical surface a line of intersection xy; in elevation this will show as a circle $x^v y^v$, whose diameter is obtained from the line $x^h y^h$ in the plan. This line of intersection will show in plan as a straight line, $x^h y^h$.

Cast the shadow of the line *acb* on this auxiliary plane P. This is not difficult because the plane P was assumed parallel to *acb*, and in this particular case, $a^v c^v b^v$ is the arc of a circle. To cast its shadow on P it is only necessary to cast the shadow of its center o^v, using the line P as a *ground line* and to draw an arc of same length and radius. We thus obtain the arc $a^{ps}c^{ps}b^{ps}$. This is the shadow of the shade line of the object on the auxiliary plane P. It will be noted that this shadow $a^{ps}c^{ps}b^{ps}$ crossed the line of intersection, made by P with the spherical surface, at the two points m^p and n^p. In plan these points would be m^h and n^h which are two points in the required shadow on the spherical surface for they are the shadows of two points in the shade line *acb* and they are also on the surface of the spherical hollow since they are on the line of intersection xy which lies in that spherical surface. With one auxiliary plane we thus obtain two points in the shadow of the hollow.


FIG·30

In Fig. 30 a number of auxiliary planes have been used to obtain a sufficient number of points, 1, 2, 3, 4, etc., of the shadow, to warrant its outline being in elevation and plan with accuracy. The shadow in plan is determined by projection from the shadow in elevation, which is found first.

74. The separate and successive steps in this method of determining the shadow of an object by the use of auxiliary planes are as follows:

1. Determine the shade line by applying to the object the projections of the ray of light.

2. Pass the auxiliary planes through the object parallel to the plane of the shade line.

3. Find the line of intersection which each auxiliary plane makes with the object.

4. Cast the shadow of the shade line on each of the auxiliary planes.

5. Determine the point or points where the shadow on each auxiliary plane crosses the line of intersection made by that plane with the object.

6. Draw a line through these points to obtain the required shadow.

75. **Problem XIV. To find the shadow on the surface of a scotia.**

This problem is similar in method and principle to that for finding the shadow of a spherical hollow. Neither the H or V projection of the surface of the scotia is a line, and we therefore must resort to some method other than that generally used. The following is the most accurate and convenient although the shadow can be found by a method to be explained in the next problem.

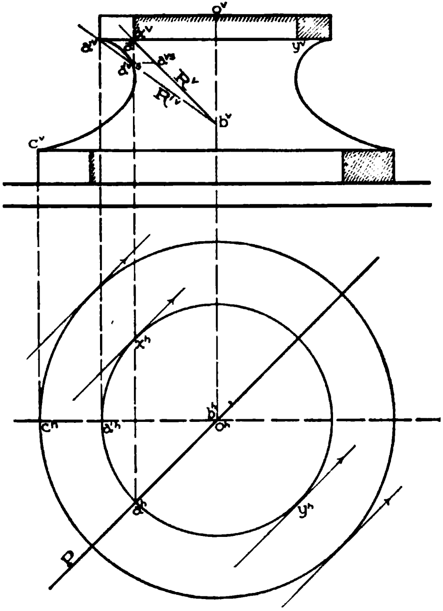
76. As in any problem in shades and shadows, the first step is to determine the shade line.

The scotia is bounded above and below by fillets which are portions of right cylinders. The shadow of the scotia is formed by the shadow of the upper fillet or right cylinder upon the surface of the scotia. We determine the shade lines of the cylinder, Problem XI, by applying to the plan the projections of the ray, Fig. 31. These determine the shade elements at x^h and y^h and also the portion of the perimeter of the fillet, $x^h a^h y^h$, which is to cast the shadow on the scotia.

In this case, as in most scotias, the shadow of the shade elements of the cylinder falls not on the scotia itself, but beyond on the H or V plane, or some other object, hence we can neglect them for the present.

Having determined the shade line, there is another preliminary step to be taken before finding its shadow. That is, to determine the highest point in the shadow a^{vs}. We do this to know where it is useless to pass auxiliary planes through the scotia. Such planes would evidently be useless between the point a^{vs} and the shade line $x^v a^v y^v$ in elevation. Also because we could not be sure that in passing the auxiliary planes we were passing a plane which would determine this highest point.

FIG. 31



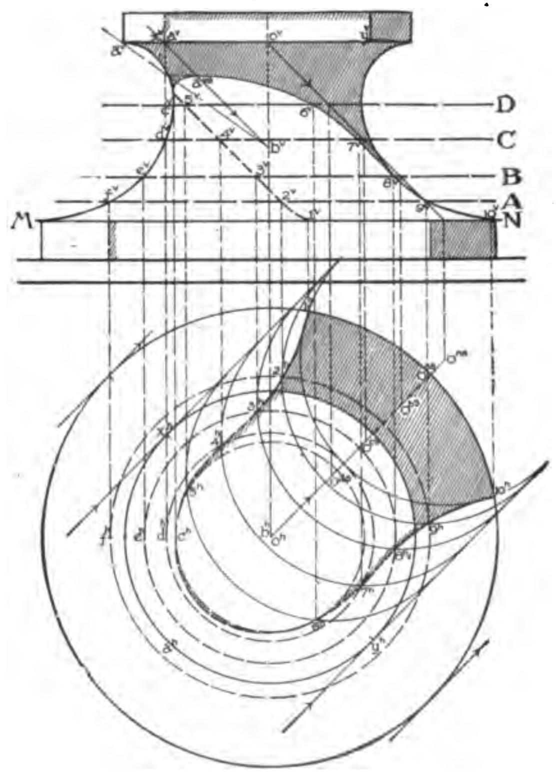
The highest point of shadow a^{vs} is determined, therefore, as follows:

The point a^h, lying on the diagonal Po^h is evidently the point in the shade line which will cast the highest point in the shadow, for, considering points in the shade line on either side of a^h, it will become evident that the rays through them must intersect the scotia surface at points lower down than the point a^{vs}.

The point a lies in a plane of light P, which passes through the axis ob of the scotia. This plane, therefore, cuts out of the scotia surface a line of intersection exactly like the profile $a^v c^v$. If we revolve the plane P and its line of intersection about the axis ob until it is parallel to V, the line of intersection will then coincide with this profile $a^v c^v$, the point a^v having moved to the point a'^v.

If, before revolving, we had drawn the projections of the ray of light, R^v, through the point a^v, they would be the lines $a^v b^v$ and $a^h b^h$. After the revolution of the plane P these projections of the ray are the lines $a'^v b^v$ and $a'^h b^h$. The point b, being in the axis, does not move in the revolution of the plane P. The point a'^{vs}, the intersection of the projection of the ray R'^v with the profile $a^{v}c^{c}$, indicates that the ray R'^{v} has pierced the scotia surface. If now the plane P is revolved back to its original position, this point a'^{vs} will move in a horizontal line in elevation to the point a^{vs}, and the point a^{vs} thus obtained is the shadow of the point a^{v} on the surface of the scotia and is also the highest point of the shadow.

FIG. 32



77. The remainder of the process is, from now on, similar to the method just explained in the previous problem. See Fig. 32.

We pass auxiliary planes, A, B, C, etc., (in this case parallel to H) through the scotia.

We determine in plan their respective lines of intersection with the scotia: they will be circles.

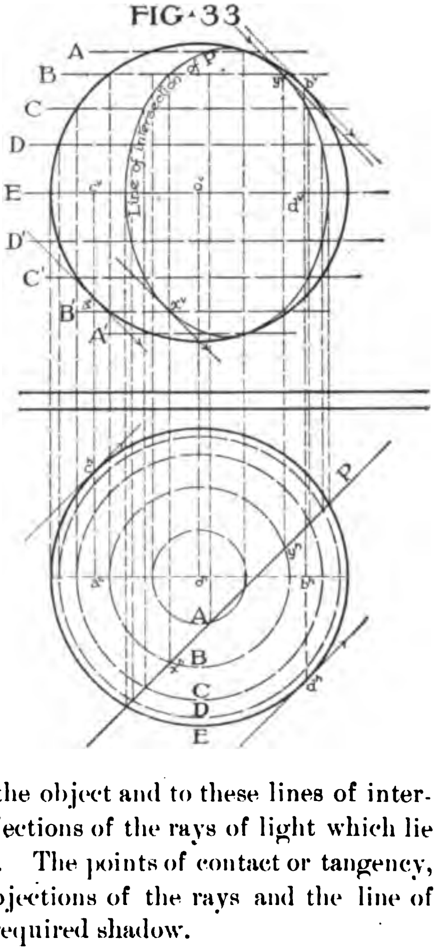
Cast the shadow of the arc $x^{h}a^{h}y^{h}$ on each of these auxiliary planes. This is done by casting the shadow of its center O and drawing arcs equal to $x^{h}a^{h}y^{h}$.

The points of intersection, 2^h, 3^h, 4^h, 5^h, 6^h, etc., are points in the required shadow in plan. The points 1^h and 10^h are the ends, where the shadow leaves the scotia, and these are determined by taking one of the auxiliary planes at the line MN. The points 1^v, 2^v, 3^v, etc., are obtained in the elevation by projection from the plan.

The shade of the lower fillet is determined by Problem XI.

78. In case the fillets are conical instead of cylindrical surfaces, as is sometimes the case in the bases of columns where the scotia moulding is most commonly found, care must be taken to first determine the shade elements of the conical surface. This supposition of conical surfaces would mean a larger arc for the shade line than the arc $x^h a^h y^h$.

FIG·33



USE OF PLANES OF LIGHT PERPENDICULAR TO THE CO-ORDINATE PLANES.

79. Another method often necessary and convenient in casting the shadows of double-curved surfaces is the use of *planes of light perpendicular to the co-ordinate planes.*

These auxiliary planes of light are passed through the given object. They will cut out lines of intersection with the object and to these lines of intersection can be applied the projections of the rays of light which lie in the auxiliary planes of light. The points of contact or tangency, as the case may be, of the projections of the rays and the line of intersection are points in the required shadow.

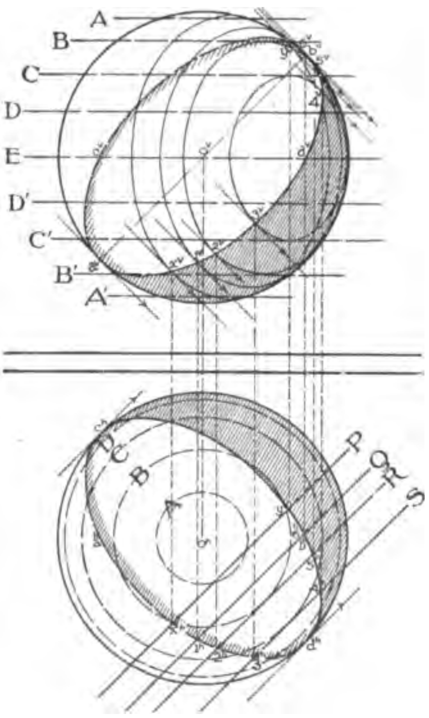
80. The use of this method will be illustrated by finding the shadow of a sphere in the following problem. The shadow of the sphere serves to illustrate this method well, but a more accur-

ate and convenient method is given later in Problem XXIX for determining the shade line of the sphere and its shadow.

81. **Problem XV. To find the shade line of a sphere.**

In Fig. 33 is shown the plan and elevation of a sphere. Through the sphere in plan, pass the auxiliary *plane of light* P, perpendicular to H. This cuts out of the sphere the "line of intersection," shown in the elevation. This "line of intersection" is determined by using the auxiliary planes A, B, C, D, etc., each plane giving two points in the line. To this line of intersection made by the *plane of light* P, with the sphere, we apply the projections of the ray and obtain two points, $x^v y^v$, in the required shade line. Other points can be determined by using a number of these planes of light, as shown in Fig. 34, P, Q, R and S.

FIG·34



The points x^v and y^v can be projected to the plan to determine the shade line there. The ends of the major axis of the ellipse a^v and b^v are determined by applying directly to the sphere the projections of the ray. The same is true of the plan.

82. ***Problem XVI. To find the shadow of pediment mouldings.**

Fig. 35 shows a series of pediment mouldings in elevation, the mouldings being supposed to extend to the left and right indefinitely. At the left is a "Right Section," showing the profile of each moulding forming the pediment.

The shadow of such an object can be most conveniently found by the use of a plane of light perpendicular to the V plane and intersecting the mouldings.

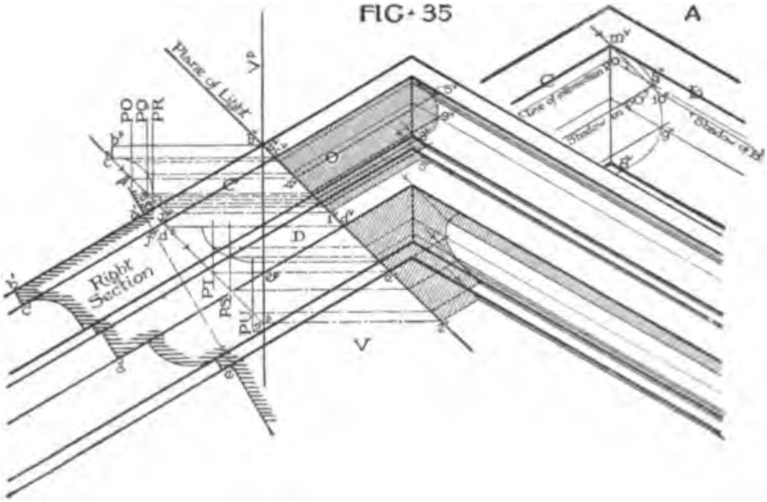
---

*Optional.

If such a "Plane of Light" (45° line) as that shown in Fig. 35 is passed through the mouldings, it will be evident that this plane will cut the mouldings along a line of intersection which can be made use of in determining the shadow of each moulding upon the others. If we find the profile projection of this line of intersection using the right section, we can apply the profile projections of rays of light to the line of intersection. It will then be evident what faces the light strikes directly and to what edges the rays are tangent.

The line of intersection in Fig. 35 made by the Plane of Light

FIG·35



is shown in vertical projection by the 45° line $a^vb^vc^vd^v$, etc. The profile $a^pb^pc^pd^p$, etc., is the profile projection of this line of intersection; the point b^p is evidently on a horizontal line to the left of the point a^v at a distance from the line V^p (*profile projection of V*) equal to $a'b'$, obtained from the *Right Section*. In the same way the point c^p is on a horizontal line to the left of c^v and at a distance from the line V^p equal to the distance $c'f''$ also obtained from the *Right Section*. In a similar manner the other points in the profile projection are found. The vertical line b^pc^p is the profile projection of the line of intersection which the Plane of Light makes with the fillet, this line in direct elevation is b^vc^v.

If we now apply to this profile projection of the line of intersection the profile projections of the ray (45° lines) we see that the fillet b^pc^p is in the light, and that the ray is tangent to its lower edge c^p. We also see that this tangent ray strikes the face D at the point l^p; this means that the shadow of the edge c falls upon the face D. Since the mouldings of the pediment are all parallel to each other, the edge c is parallel to the face D, therefore, (30) the shadow of c on D will be parallel to C itself. This shadow is found in the elevation by drawing a horizontal line from the point l^p back to the *Plane of Light.* This operation gives the point 1^v and we draw through the point 1^v a line parallel to the edge C, as a part of the required shadow. Evidently that portion of the elevation between the edge C and its shadow will be in shadow.

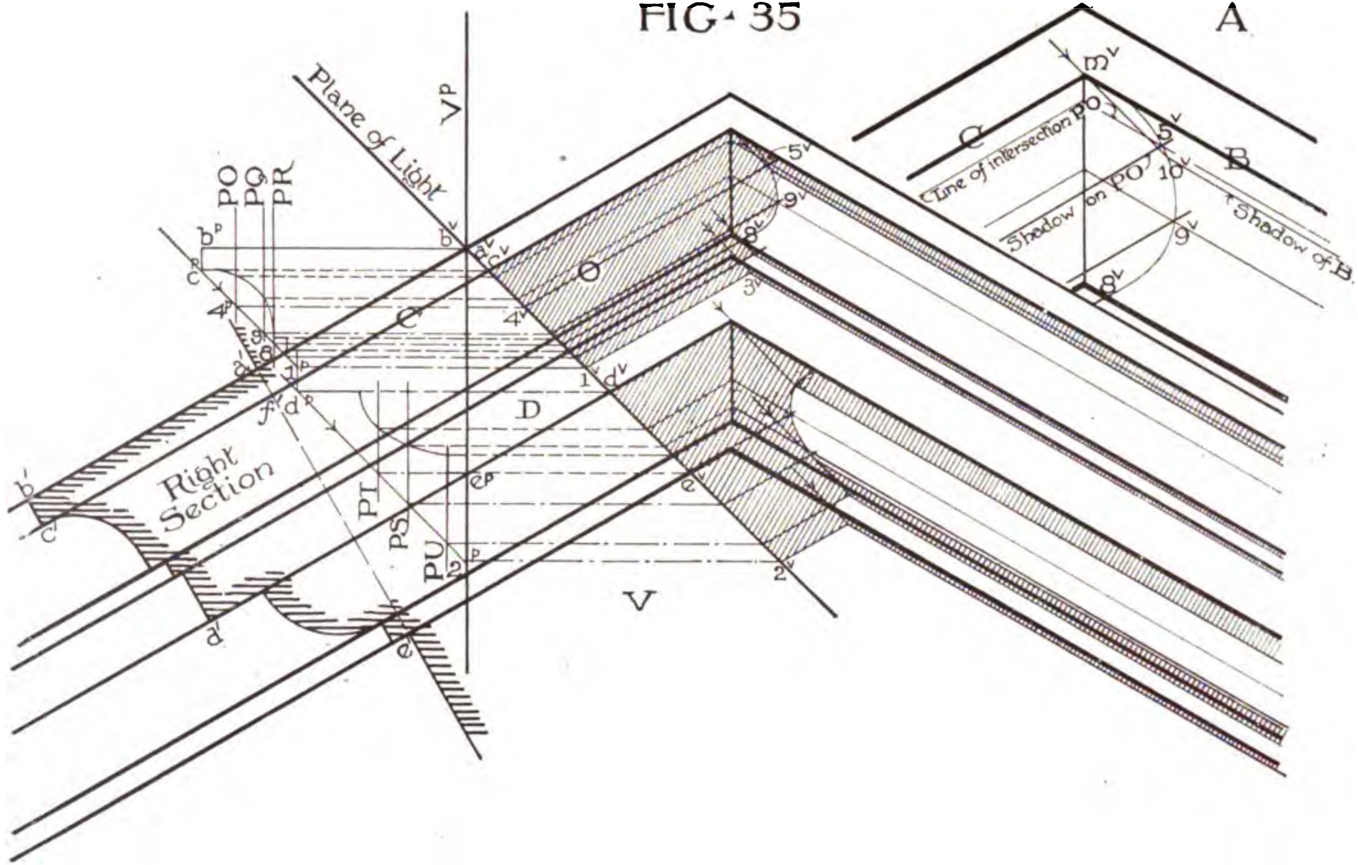
In a like manner the edge d^p is found to cast its shadow on the plane V, below the pediment mouldings proper, and its shadow is of course a line drawn through 2^v parallel to the lines of the mouldings.

To return to the shadow of the edge C on the face D. It will be noticed that, if this is extended far enough, it will cross the pediment mouldings on the right-hand slope; as these are not parallel to the edge C, the shadow on them will not be a parallel line and we must use a separate, though similar, method for determining this portion of the shadow.

If auxiliary planes O, Q and R parallel to V are passed through the crowning moulding, they will cut out of it lines of intersection which will be parallel to the other lines of the pediment. (See the enlarged diagram at A showing the line of intersection of the auxiliary plane O.)

If we cast the shadow of the edge C on this plane O, by drawing the 45° line from c^p to the line PO (the profile projection of O) and from the point 4^p draw a horizontal line back to the *Plane of Light,* we shall obtain the line O (see "shadow on PO" in diagram A). This shadow will cross the *Line of intersection of PO* at the point 5^v. The point 5^v will be one point in the shadow of the edge C (indefinitely extended) on the right-hand slope of the pediment. Other points, 8^v and 9^v, can be found in a like manner by use of the auxiliary planes Q and R. Through a sufficient number of these points the curve $5^v9^v8^v$ is drawn. This curve is the required shadow. The shadow of the end of the edge C is found by drawing a 45° line from the point m^v (diagram A) to the

FIG. 35

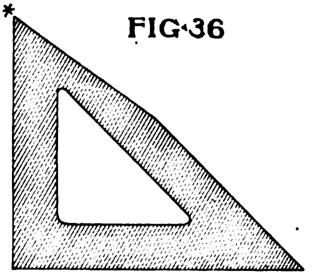

A
B
C
m^v
5^v
10^v
9^v
8^v
Line of intersection PO
Shadow on PO
Shadow of B
Plane of Light
V^P
PO
PQ
PR
b^P
c^P
4^P
9
8
a'
1^P
f'
d^P
b^v
a^v
c^v
O
4^v
3^v
C
1
d^v
D
e^v
e^P
2^P
2^v
PT
PS
PU
V
Right Section
b'
c'
d'
e'

curve. The point of intersection, 10^v, is the shadow of the end of the edge C. It is also the beginning of the shadow of the edge B on the right-hand slope, which shadow is parallel to B.

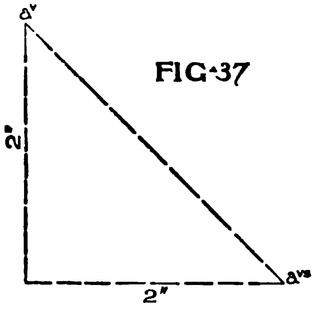
The remaining shadows of the pediment are found in the same manner, and may be understood, from the diagram, without a detailed explanation.

SHORT METHODS OF CONSTRUCTION.

83. The following problems illustrate short and convenient methods of construction for determining the shadows of lines, surfaces and solids, in the positions in which they commonly occur in architectural drawings. These methods here worked out with regard to the co-ordinate planes apply also to parallel planes.



FIG·36



FIG·37

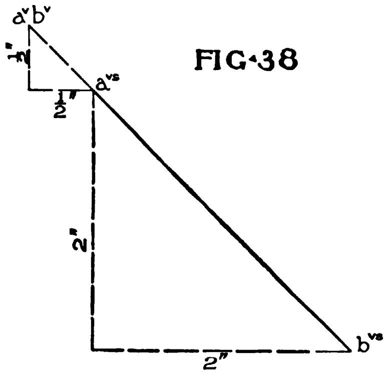
84. They will be found to be of great assistance in casting the shadows in architectural drawings. The latter seldom have the plan and elevation on the same sheet, and these methods have been devised to enable the shadows to be cast on the elevation without using construction lines on the plan or profile projection. Such distances as are needed and obtained from the plan, can be taken by the dividers and applied to the construction in the elevation.

In casting shadows it will be found convenient to have a triangle, one of whose angles is equal to the true angle which the ray of light makes with the co-ordinate plane. See Fig. 36. With such a triangle the revolved position of the ray of light can be drawn immediately without going through the operation of revolving the ray parallel to one of the co-ordinate planes.

85. **Problem XVII. To construct the shadow on a co-ordinate plane of a point.**

It will lie on the 45° line passing through the point and representing the projection of the ray of light on that plane. It will be situated on the 45° line at a distance from the given point, equal to the diagonal of a square, the side of which is equal to the distance of the point from the plane.

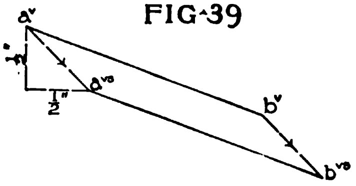
Given the vertical projection of the point *a* situated 2 inches from the V plane, to construct its shadow on V. Fig. 37.



FIG·38

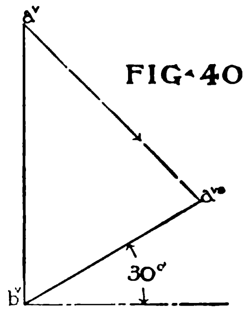
From the point a^v draw the 45° degree line $a^v a^{vs}$ equal in length to the diagonal of a square whose sides measure 2 inches. Then a^{vs} is the required shadow.

FIG·39



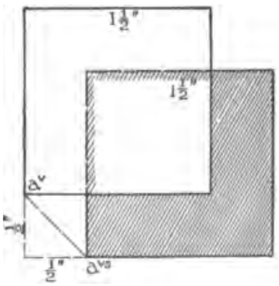
86. **Problem XVIII. To construct the shadow of a line perpendicular to one of the co-ordinate planes.**

(1) It will coincide in direction with the projection of the ray of light upon that plane, without regard to the nature of the surface upon which it falls.



FIG·40

FIG·41



(2) The length of its projection upon that plane will be equal to the diagonal of a square, of which the given line is one side.

Given the vertical projection of the line *ab* perpendicular to

V, 2 inches long and $\frac{1}{2}$ inch from V, to construct its shadow on V. See Fig. 38. Find the shadow of the point a^v by Problem XVII.

From the point a^{vs} draw the 45° line $a^{vs}b^{vs}$ equal to the diagonal of a square 2 inches on each side.

86. **Problem XIX. To construct the shadow of a line on a plane to which it is parallel.**

(1) It will be parallel to the projection of the given line.

(2) It will be equal in length to the projection of the line.

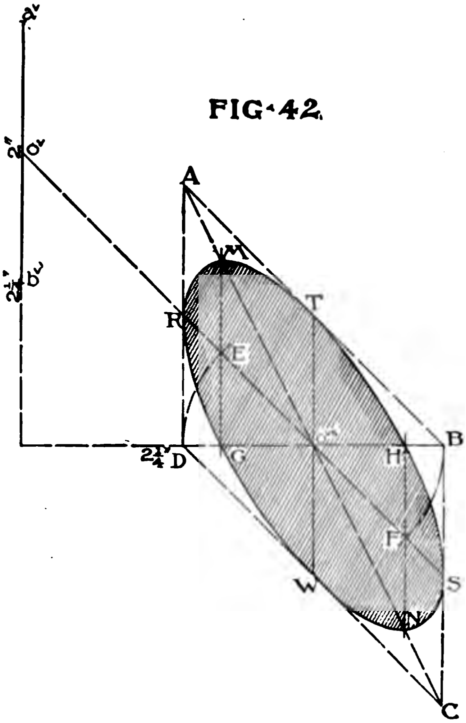
Given the vertical projection of the line ab, parallel to V, 2 inches in length and $\frac{1}{2}$ inch from V, to construct its shadow on V. See Fig. 39.

Find the shadow of a^v by Problem XVII.

Draw $a^{vs}b^{vs}$ parallel and equal in length a^vb^v.

87. **Problem XX. To construct the shadow of a vertical line on an inclined plane parallel to the ground line.**

It makes an angle with the horizontal equal to the angle which the given plane makes with H.


FIG·42.

Given the vertical projection of a vertical line ab, its lower end resting on a plane parallel to the ground line and making an angle of 30° with H, to construct its shadow on this inclined plane. See Fig. 40. Through the point b^v draw the 30° line b^va^{vs}. The point a^{vs}, the end of the shadow, is determined by the intersection of the 45° line drawn through the end of the line a^v.

88. **Problem XXI. To construct the shadow on a co-ordinate plane of a plane which is parallel to it.**

(1) It will be of the same form as that of the given surface.

(2) It will be of the same area.

If the plane surface is a circle, the shadow can be found by finding the shadow of its center, by Problem XVII, and with that as a center describing a circle of the same radius as the given circle.

Given a plane parallel to V, ½ inch from V and 1½ inches square, to construct its shadow on V. See Fig. 41.

Find the shadow of any point a^v for example, by Problem XVII. On that point of the shadow construct a similar square whose side equals 1½ inches.

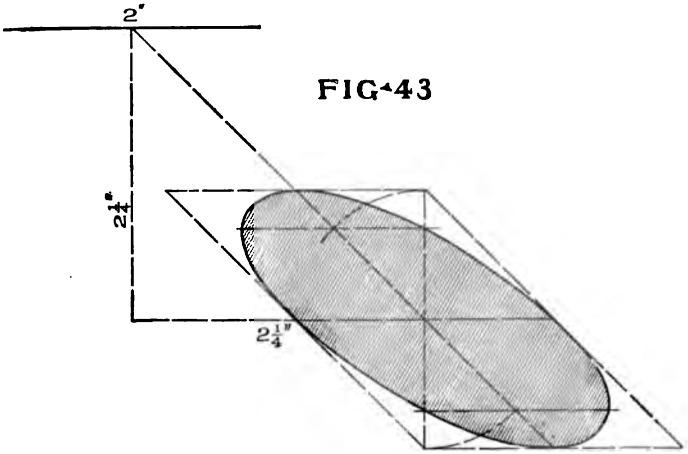


FIG-43

89. **Problem XXII. To construct the shadow on V of a circular plane which is parallel to H, or which lies in a profile plane.**

Given $a^v o^v b^v$, the projection of a circular plane perpendicular to V and H, 2 inches in diameter, its center being 2¼ inches from V, to construct the shadow on V. Fig. 42. The shadow of o^v, the center of the circular plane is found by Problem XVII. About o^{vs} as a center, construct the parallelogram ABCD made up of the two right triangles ADB and DBC, the sides adjacent to the right angles being equal in length to the diameter, 2 inches, of the circular plane. Draw the diameters and diagonals of this parallelogram. The diameter TW is equal to the diameter of the given circle and parallel to it.

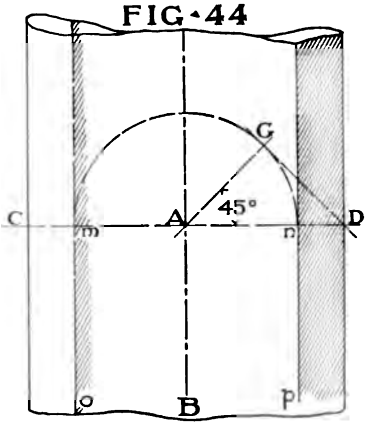
With o^{vs} as a center and OD and OB as radii, describe the arcs cutting the major diameter of the parallelogram in the points

E and F. Through E and F draw lines parallel to the short diameter, cutting the diagonals in the points G, H, M and N. These last four points and the extremities of the diameters R, S, T, and W, are eight points in the ellipse which is the shadow of the given circular plane on V. A similar construction is followed for finding the shadow on V of a circular plane parallel to H. Fig. 43.

90. **Problem XXIII. To construct the shade line of a cylinder whose axis is perpendicular or parallel to the ground line.**

Given the elevation of a cylinder, its axis being AB perpendicular to H. To construct shade lines. Fig. 44.

FIG. 44



Let CD be any horizontal line drawn through the cylinder.

Construct the 45° isosceles triangle AGD on the right half of the diameter.

With the radius AG describe the semi-circular arc mGn, cutting the horizontal line CD in the points m and n.

These two points will determine the shade elements mo and np.

91. **Problem XXIV. To construct the shadow on a plane (parallel to its axis) of a circular cylinder whose axis is either perpendicular, or parallel to the ground line.**

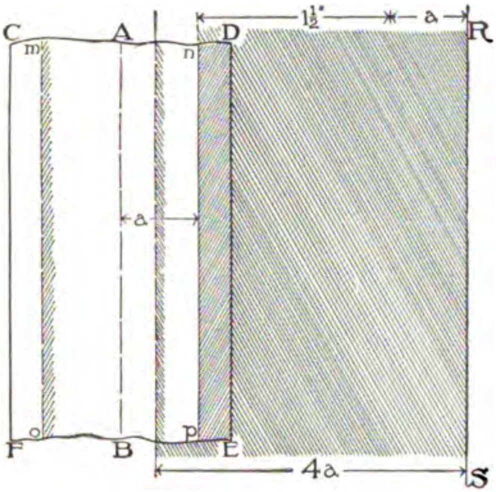
Let a = the distance, in the elevation, between the projection of the axis of the cylinder and the projection of the visible shade element. Let b = the distance between the axis of the cylinder and the plane on which the shadow falls, to be obtained from the plan.

Then the distance, between the visible shade element and its shadow on the given plane, will be equal to $a+b$.

The width of the shadow on the given plane will be equal to $4a$.

Given the circular cylinder CDEF (Fig. 45), its axis AB perpendicular to H. To construct its shadow on the V plane which is $1\frac{1}{2}$ inches distant from the axis AB. The shade elements mo and np can be constructed by Problem XXIII. Draw RS the shadow of the shade element *np*, parallel to *np*, and distant from it $a + 1\frac{1}{2}$ inches. The width of the shadow on the given plane will be 4 times the distance A*n*.

FIG·45



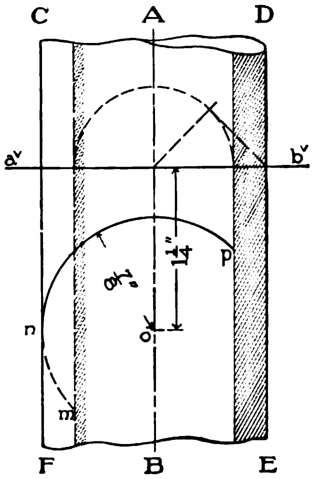
92. **Problem XXV. To construct the shadow on a right cylinder of a horizontal line.**

a. It will be the arc of a circle of the same radius as that of the cylinder.

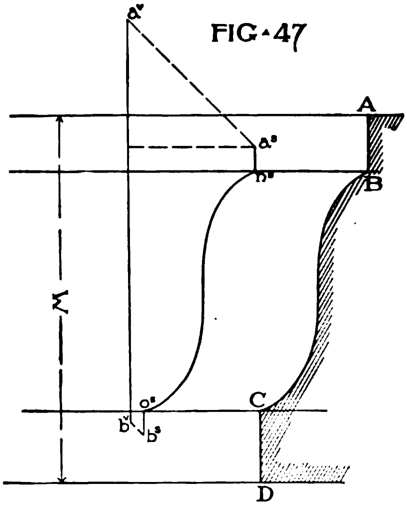
b. The center of the circle will be on the axis of the cylinder as far below the given line as that line is in front of the axis.

Given a right circular cylinder CDEF, whose diameter is $1\frac{3}{4}$ inches, and a horizontal line *ab*, $1\frac{1}{4}$ inches in front of the axis of the cylinder. To construct the shadow. Fig. 46.

FIG·46



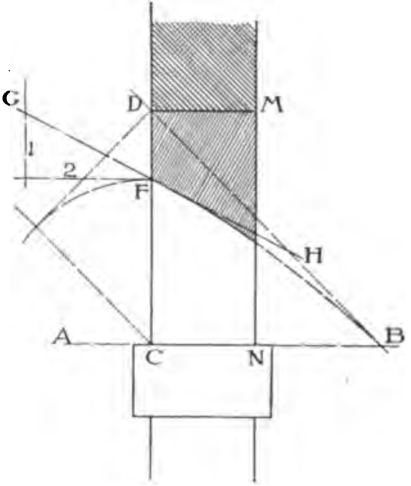
FIG·47



Locate the point *o* on the axis $1\frac{1}{4}$ inches below a^vb^v. With

o as a center, and radius equal to $\frac{7}{8}$ inch describe the arc mnp, the required shadow.

FIG-48



93. **Problem XXVI. To construct the shadow of a vertical line on a series of mouldings which are parallel to the ground line.**

The shadow reproduces the actual profile of the mouldings.

Given a vertical line a^vb^v which casts a shadow on the moulding M, which is parallel to the ground line, and whose profile is shown in the section ABCD. The line a^vb^v, is 1 inch in front of the fillet AB. To construct its shadow, Fig. 47:

Construct the shadow on the fillet AB, of the end of the line a^v, or any other convenient point in the line, by Problem XVII. From the point a^s the shadow of the line reproduces the profile ABCD and we obtain $a^sn^so^sb^s$, the required shadow.

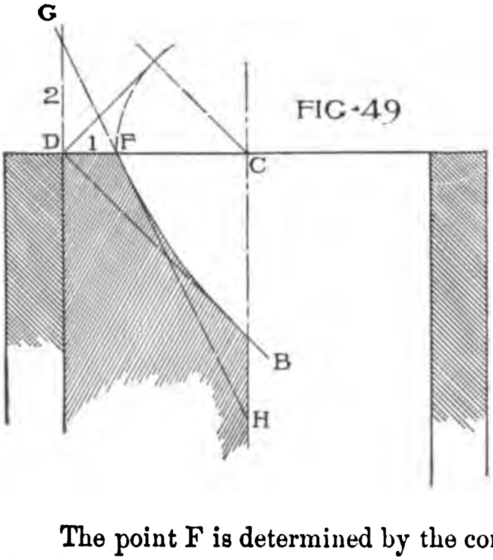


FIG-49

94. **Problem XXVII. To construct the shadow on the intrados of a circular arch in section, the plane of the arch being in profile projection.**

Let AB (Fig. 48) be the "springing line" of the arch. Let CD be the radius of the curve.

The point F is determined by the construction used in finding the shade element of a cylinder. Problem XXIII. At the point F draw the line GH, with an inclination to the "horizontal" of 1 in 2. Through the point D draw the 45° line DB. The curve of the line of shadow will be tangent to these two lines at the points F and B. The required shadow is that portion of the curve between the lines DC and MN.

A similar construction is used in the case of a hollow semi-cylinder when its axis is vertical, except, that the line GH has then an inclination to "the horizontal" of 2 in 1. Fig. 49.

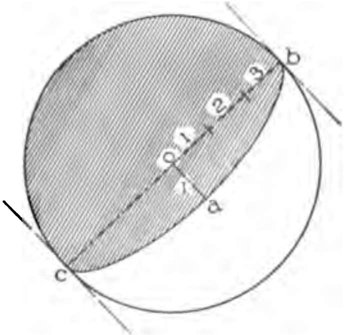
95. **Problem XXVIII. To construct the shadow of a spherical hollow with the plane of its face parallel to either of the co-ordinate planes.**

The line of shadow is a semi-ellipse. The projections of the rays of light tangent to the circle determine the major axis. The semi minor axis is equal to $\frac{1}{3}$ the radius of the circle.

Given the vertical projection of a spherical hollow, the plane of its face parallel to V. Fig. 50.

Determine the ends of the major axis by drawing the projections of the rays of light tangent to the hollow. The semi-minor axis, *oa*, equals $\frac{1}{3}$ the radius *ob*. On *bc* and *oa* construct the semi-ellipse, the required shadow.

FIG. 50



96. **Problem XXIX. To construct the shade line and shadow of a sphere. Fig. 51.**

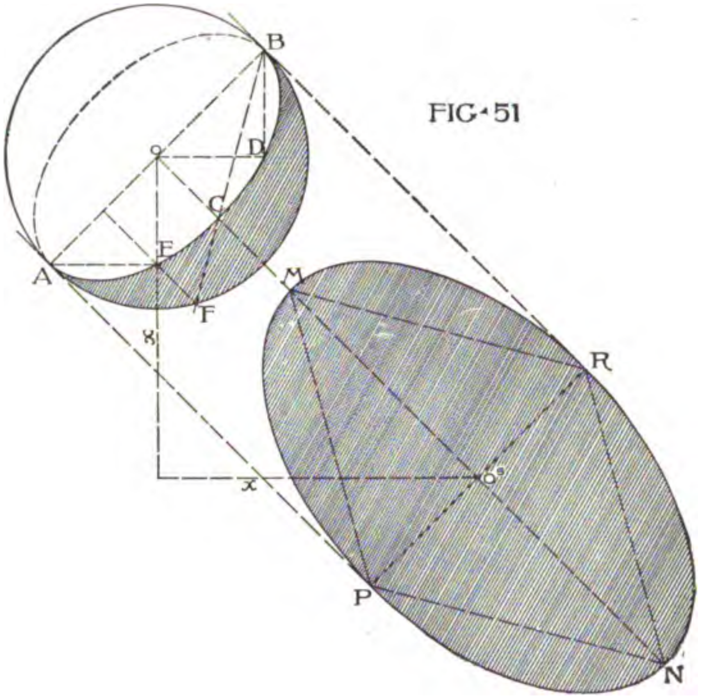
Let the circle whose center is *o* be the vertical projection of a sphere whose center is at a distance *x* from the V plane.

The shade line will be an ellipse. The major axis of this ellipse is determined by the projections of the rays of light tangent to the circle. The semi minor axis and two other points can be determined as follows:

Through the points, A, *o*, and B, draw vertical and horizontal lines, intersecting in the points E and D.

The points E and D are two points in the required shade line.

Through the point E draw the 45° line EF. Through the point F, where this line intersects the circle, and the point B, draw the line FB. The point C, where this line FB intersects the 45° line through the center of the sphere, *o*, is the end of the semi-minor axis. The shadow of the sphere on the co-ordinate plane will also be an ellipse. The center of this ellipse, o^s, will be the shadow of the center of the sphere. It will be determined by Problem XVII. The ends of the major axis MN, will be on the projection of the ray of light drawn through the center of the sphere. The minor axis PR will be a line at right angles to this through the point o^s. Its length will be determined by the projections of the rays of light BR and AP tangent to the circle, and is equal to the diameter of the sphere. The points M and N, which determine the ends of the major axis, are the apexes of equilateral triangles PMR and PNR, constructed on the minor axis as a base.



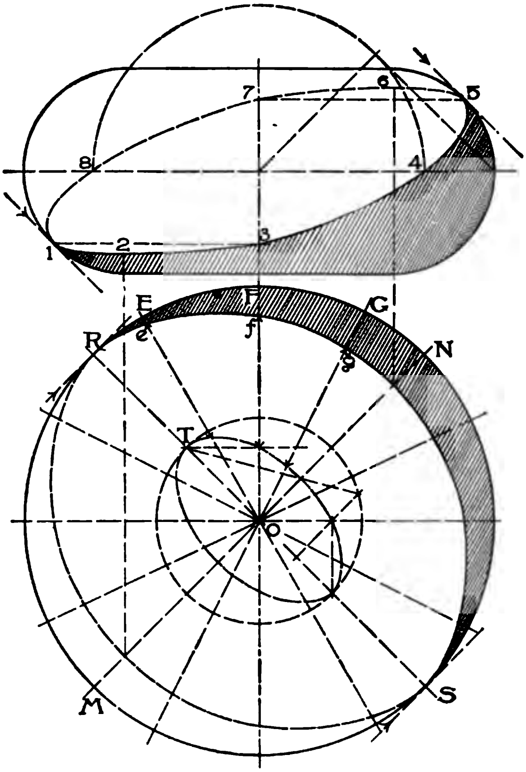
FIG·51

97. Problem XXX. To construct the shade line of a torus.

Fig. 52, in elevation: The points 1 and 5 can be determined by drawing the projections of the rays of light tangent to the elevation. Since the shade line is symmetrical on either side of the line MN in plan, the points 3 and 7 can be found from 1 and 5, by drawing horizontal lines to the axis. The points 4 and 8 are determined by the construction used in finding the shade elements of a cylinder. Problem XXIII.

The above points can be determined without the use of plan.

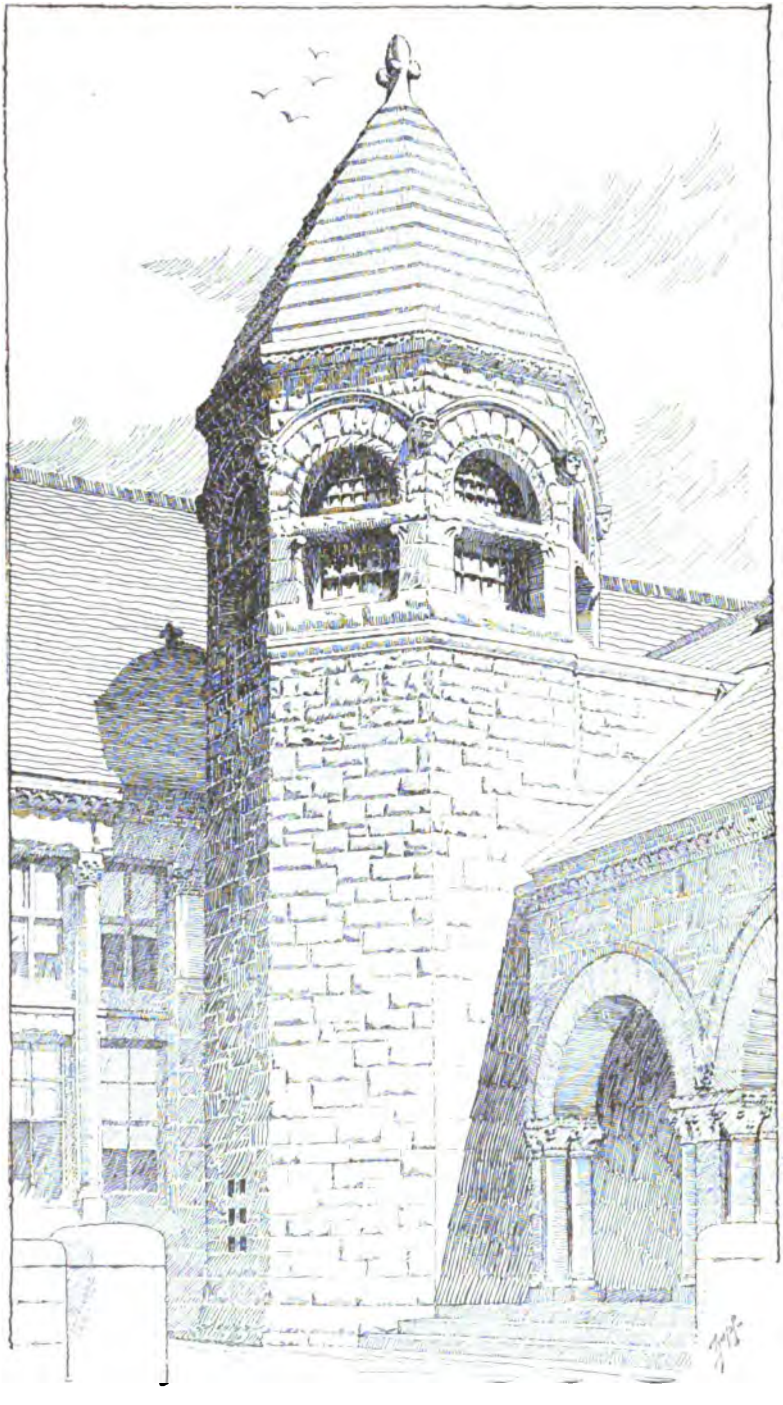
FIG. 52



The highest and lowest points in the shade line, 2 and 6, can be found only by use of plan. It is not necessary, as a rule, to determine accurately points 2 and 6. The shade line in plan will be, approximately, an ellipse whose center is *o*. The ends of the major axis R and S, are determined by the projections of the rays of light tangent to the circle. Other points can be determined without the use of the elevation as follows: With center *o*, construct the plan of a sphere whose diameter equals that of the circle which generated the torus. Determine the shade line by Problem XXIX. Draw any number of radii OE, OF, OG, etc.

On these radii, from the points where they intersect the shade line of the sphere, lay off the distance RT, giving the points *e*, *f* and *g*. These are points on the required shade line.

EXAMINATION PAPER.



TOWER CONVERSE MEMORIAL LIBRARY, MALDEN, MASS.
H. H. Richardson, Architect.
Note treatment of shadows in a perspective drawing.

NOTE.—The problems are to be worked out on the plates accompanying the Instruction Paper, and outlines are *not to be redrawn*.

SHADES AND SHADOWS.

EXAMINATION PLATES.

98. **General Directions.** Plates are to be drawn in pencil.

Show distinctly and leave all construction lines.

Shadows are to be cross-hatched lightly, and their outline drawn with a distinct black line.

PLATE I.

99. See directions on plate.

PLATE II.

100. Find the shadows of lines *ab*, etc., in Problems XIV-XVI.

101. In Problem XVII find the shadow of line *ab* on the planes A, B, and C.

102. In Problem XVIII find the shadow of plane *abcd*.

PLATE III.

103. See directions on plate.

PLATE IV.

104. See directions on plate.

PLATE V.

105. In Problem XXV find all the shadows on the steps and the shadows on the co-ordinate planes in plan and elevation. Letter carefully the various planes in elevation and plan.

106. In Problem XXVI find all the shades and shadows of the cylinder and its shadows on the co-ordinate planes.

PLATE VI.

107. In Problems XXVIII and XXIX find the shades and shadows of objects and their shadows on the co-ordinate planes.

108. In Problem XXX, C is a square projection or fillet on the V plane. Below this fillet and also applied to the V plane are portions of two cylinders, DD, which support the fillet C. Find the shades and shadows in elevation only.

PLATE VII.

109. Problem XXXI, given a spherical hollow, its plane parallel to V, find its shadow.

110. Problem XXXII, given a scotia moulding, the upper fillet of which is the frustum of a cone, the lower fillet is a cylinder. Find its shadow in elevation and plan.

*PLATE VIII.

112. Problem XXXIII shows a series of pediment mouldings applied to a vertical wall A. Find the shadows on the mouldings and the shadows of the mouldings on the vertical plane A.

PLATE IX.

113. In Problem XXXIV find the shadows of a given window.

114. In Problem XXXV find the shadows of the given keyblock and the shadow of the keyblock on the vertical wall to which it is applied. Use the short methods of construction and use the plan only from which to take distances.

PLATE X.

115. Problem XXXVI. Given the upper portion of a Doric order, the column being engaged to the vertical wall V, see plan. The entablature breaks out over the column, see plan. Find all the shadows, using the short methods of construction and use the plan only to obtain required distances.

PLATE XI.

116. Problem XXXVII. Given a rectangular niche, as shown by the plan, having a circular head as shown by the elevation. Situated in the niche is a pedestal in the form of truncated square pyramid. This pedestal has on its four side faces projections as shown in the elevation and plan. On the pedestal rests a sphere. Find all the visible shadows in the elevation. Use the short methods of construction and use the plan only for determining distances.

117. Problem XXXVIII. Given a niche in the form of a spherical hollow. The profile of the architrave mouldings is shown at A. Find all the shadows. Use the short methods of construction.

PLATE XII.

118. Problem XXXIX. Given the lower part of a column standing free from a vertical wall, and resting on a large square base, the base having a moulded panel in its front face. At the foot of the vertical wall is a series of base mouldings, the lower ones cutting into the side of the square base on which the column stands, see plan. Find all the visible shadows, using the short methods of construction.

*Optional.

SHADES & SHADOWS

PLATE 1

1. Define shade.

2. Define shadow.

3. Define umbra.

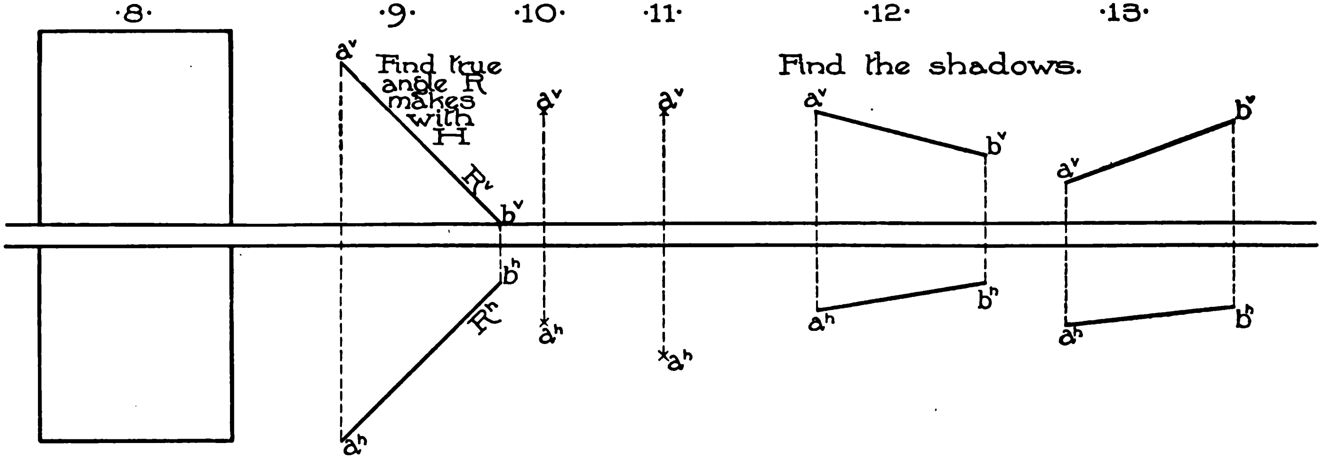
4. What is a shade line?

5. What is a plane of light?

6. What is true of the shadow of a line on a plane to which it is parallel?

7. What is true of the shadow of a line on a plane to which it is perpendicular?

8. Draw the diagonals of cube which represent the projections of the ray of light.



Find true angle R makes with H

Find the shadows.

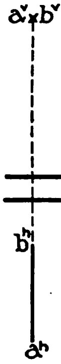
DATE

NAME

SHADES & SHADOWS

PLATE II

·14·



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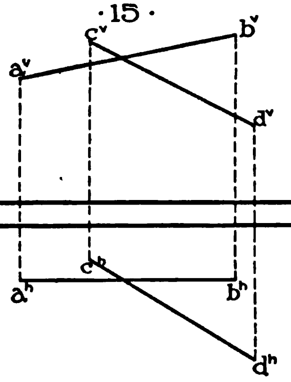

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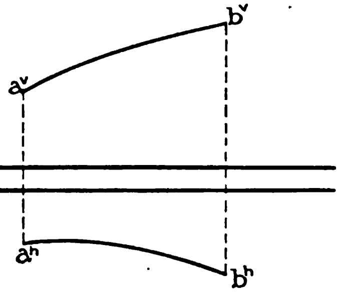

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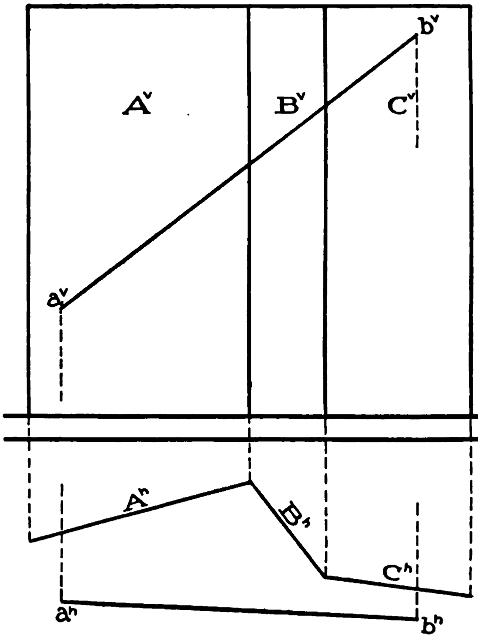

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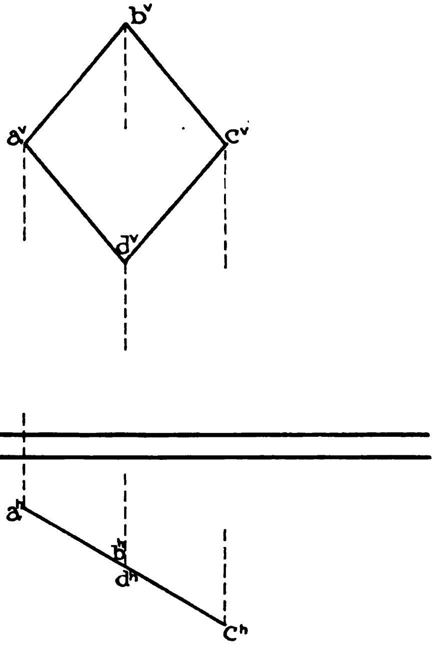

DATE NAME

SHADES & SHADOWS PLATE III

Find shade of objects and shadows on V and H.

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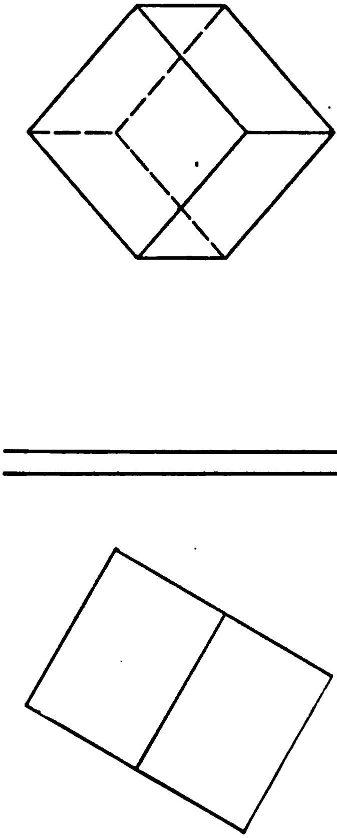

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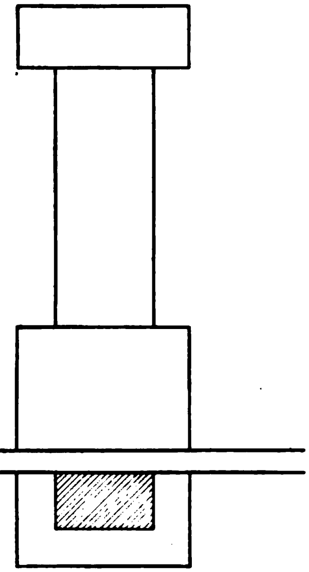

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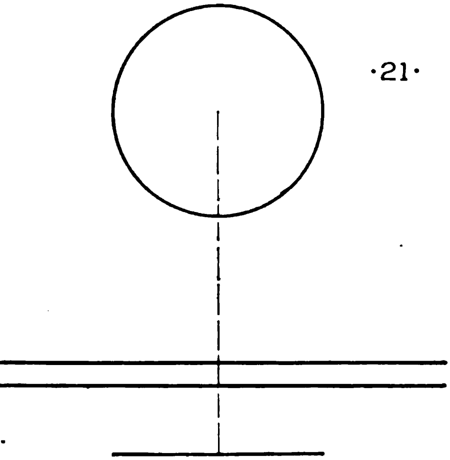

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SHADES & SHADOWS

PLATE IV

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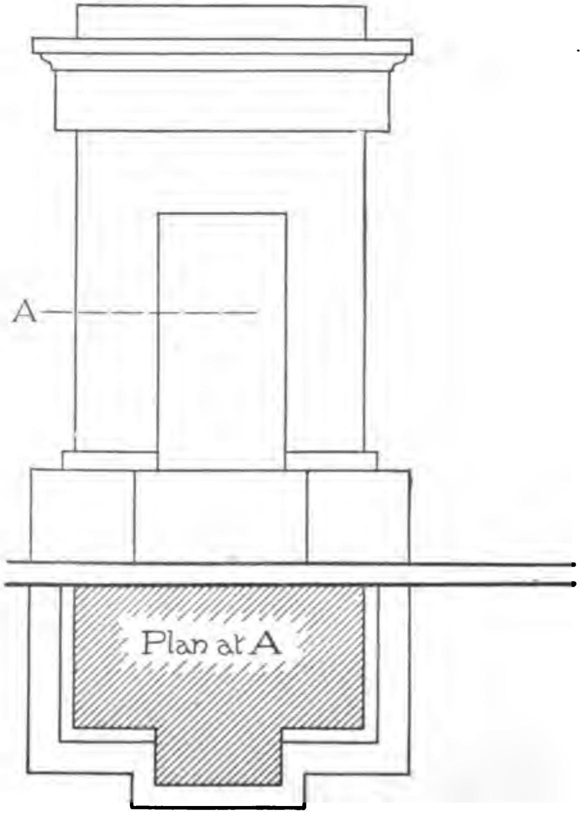

Find shadows of object on V and H

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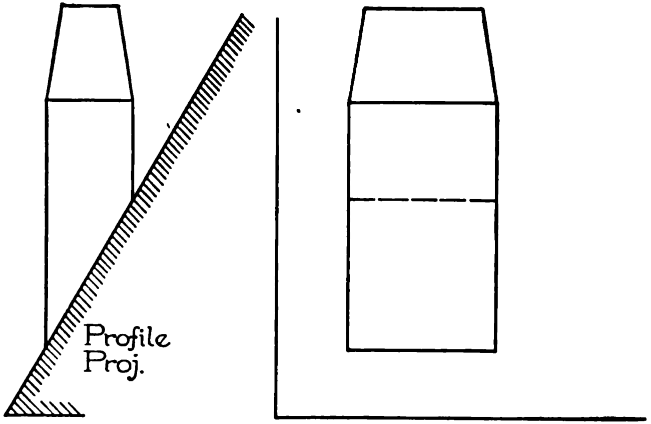

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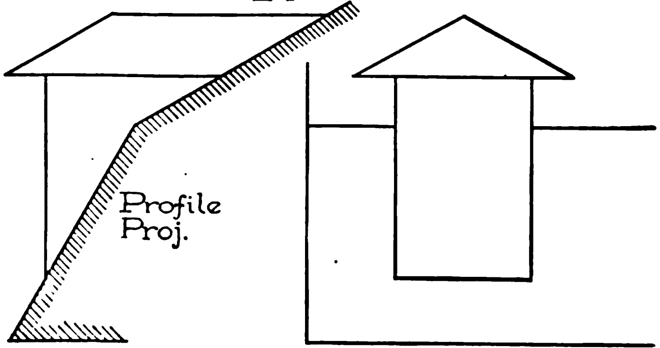

In 23 and 24 find shadows in elevation only.

DATE

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SHADES & SHADOWS PLATE V

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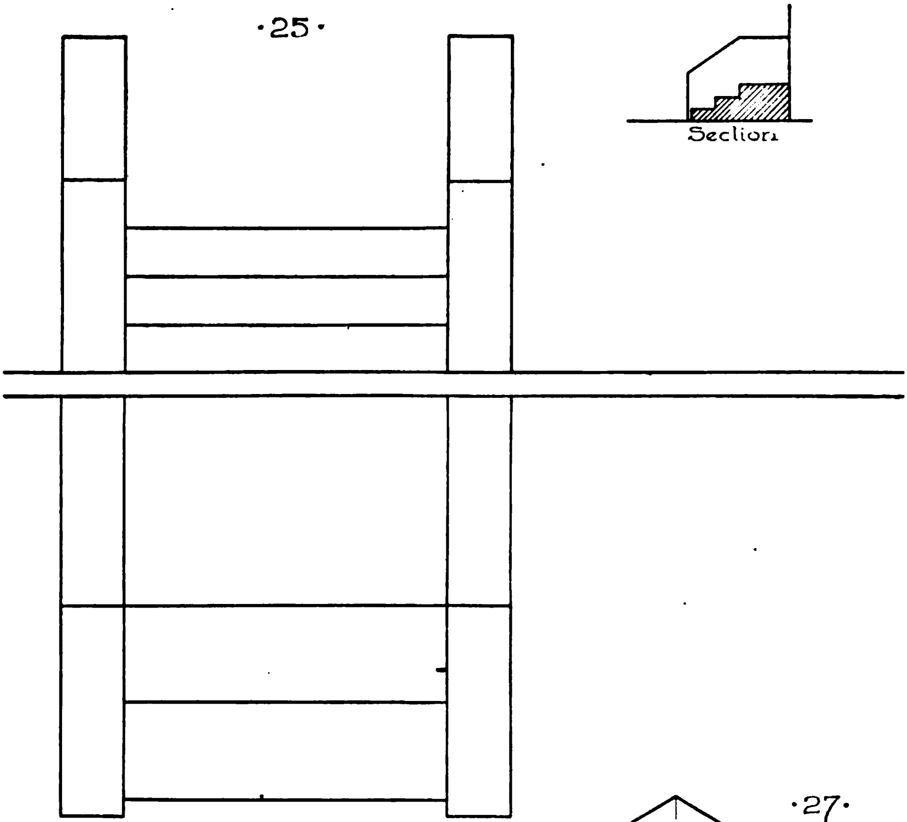

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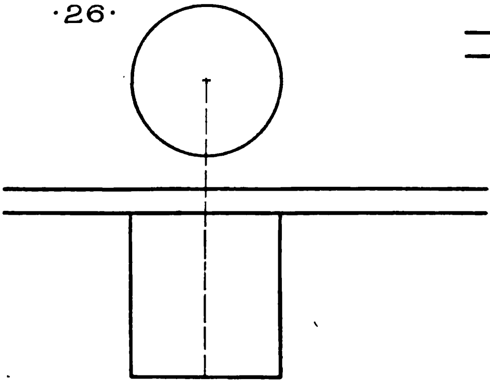

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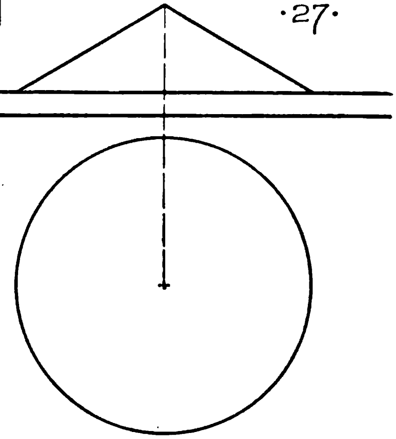

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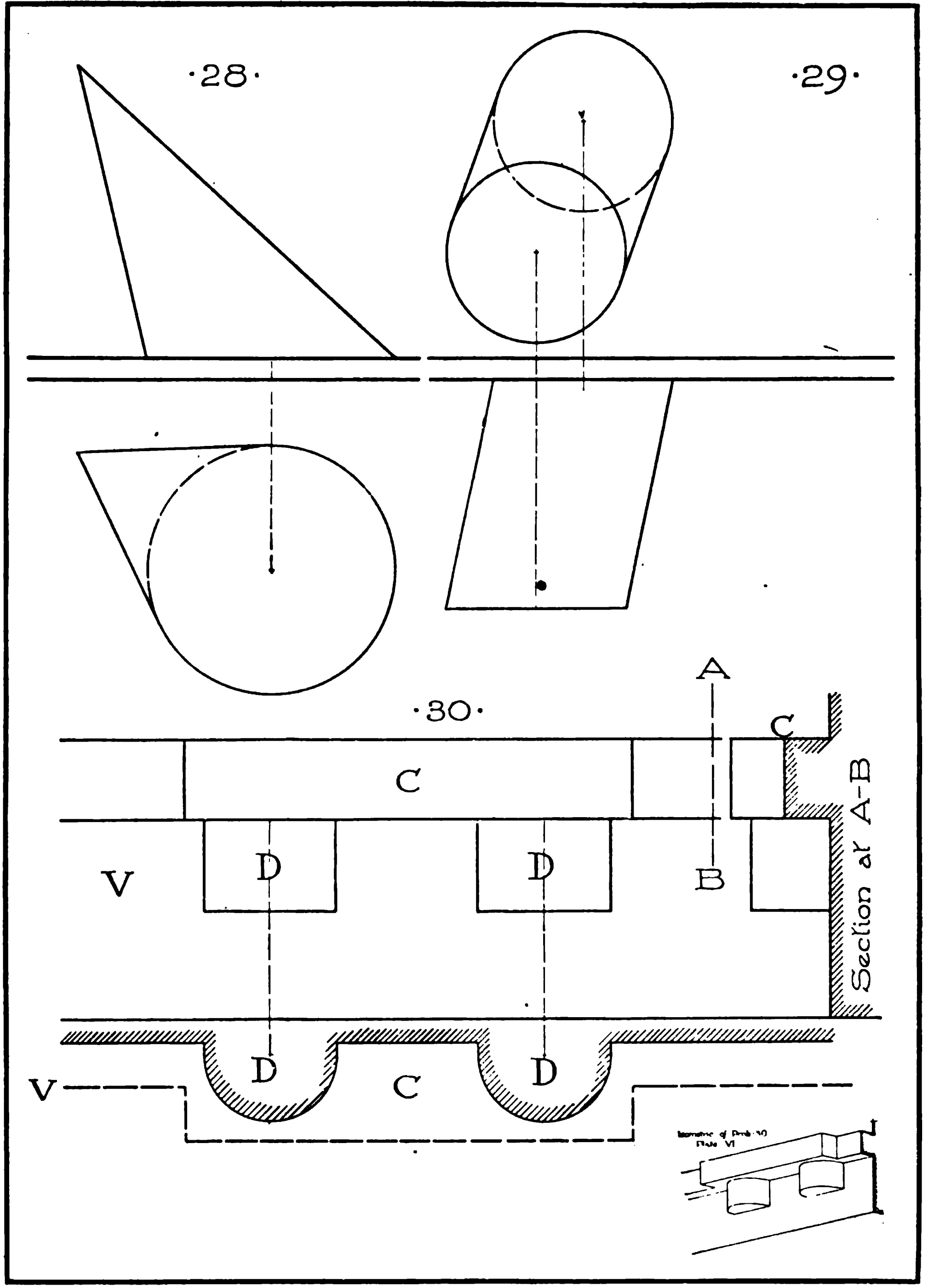
SHADES & SHADOWS

PLATE VI



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SHADES & SHADOWS

PLATE VII

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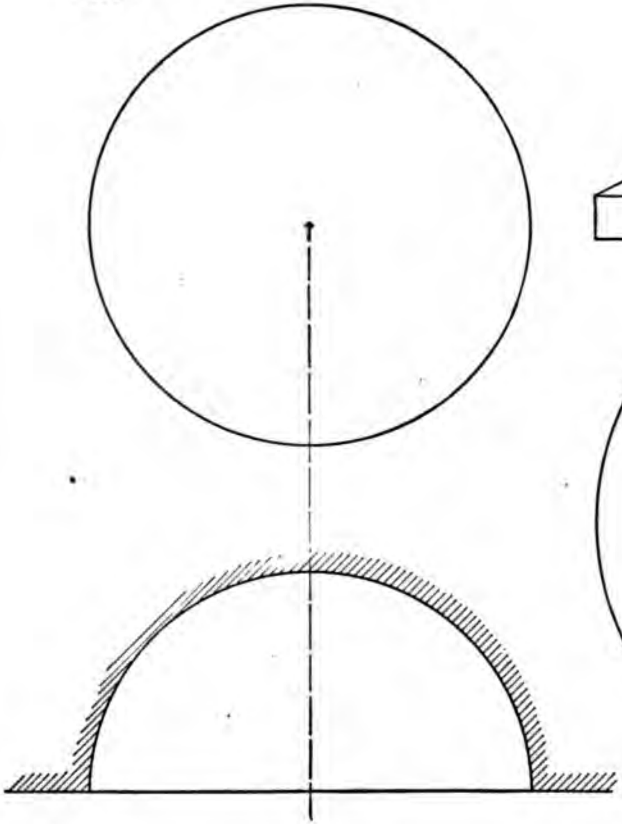

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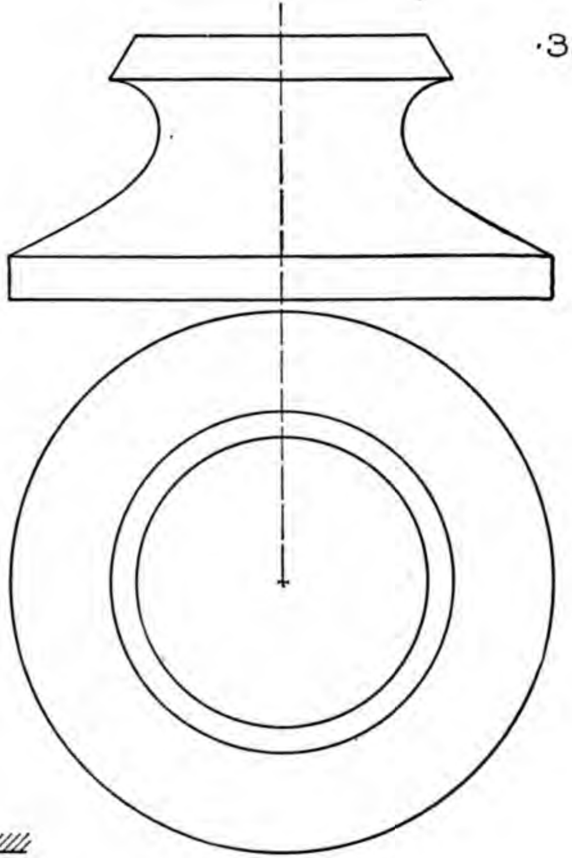

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SHADES & SHADOWS

PLATE VIII

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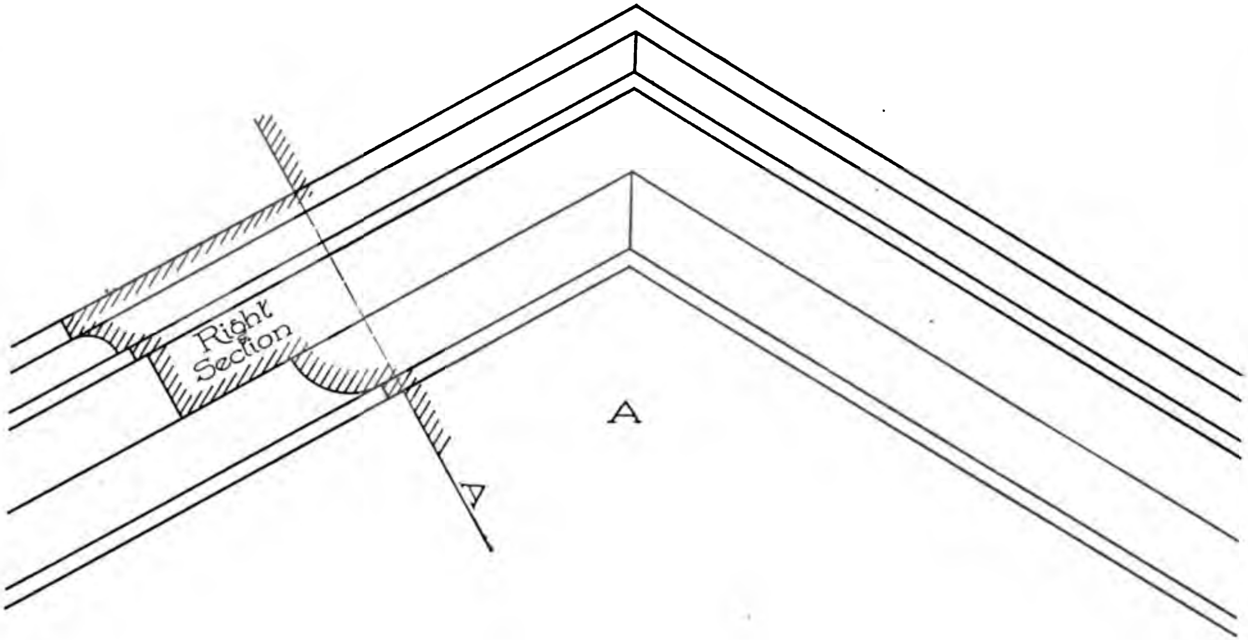

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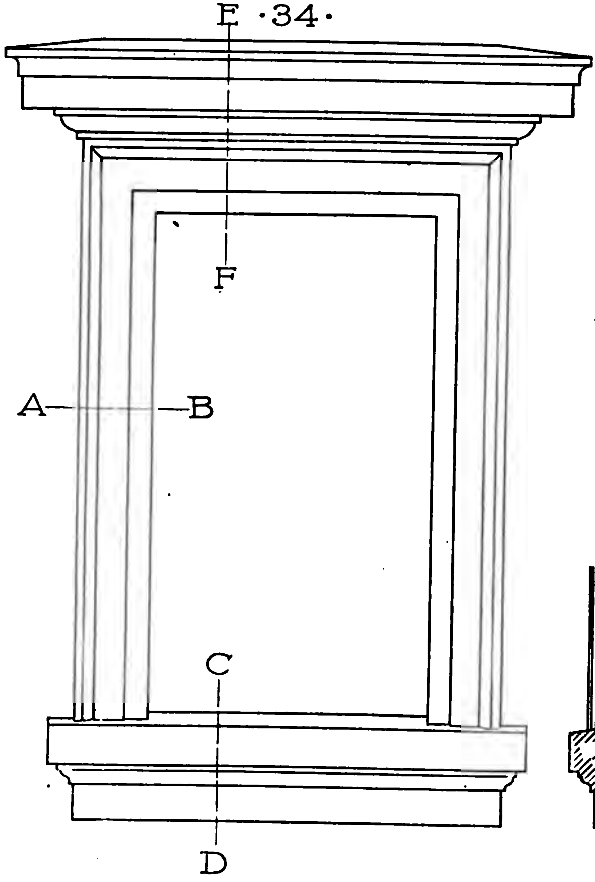
SHADES & SHADOWS

PLATE IX



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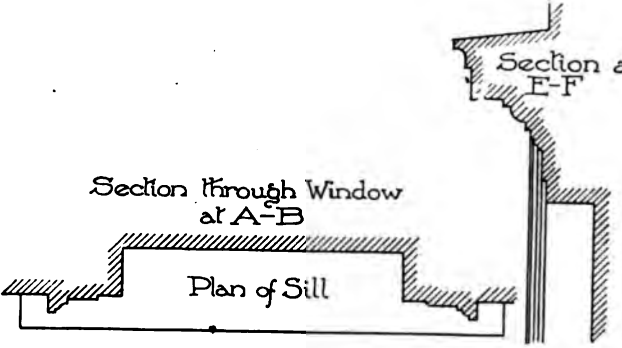
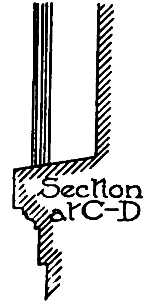
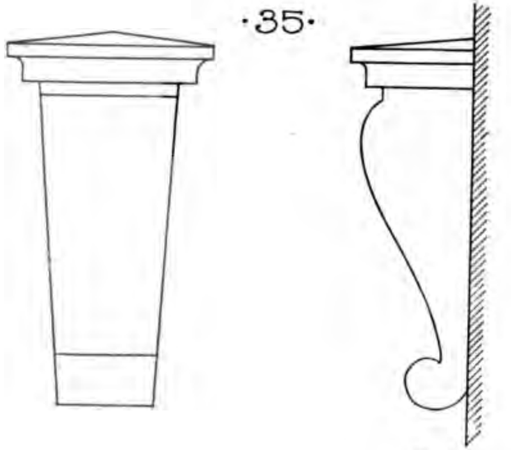


Section at E-F

Section through Window at A-B



Section at C-D



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Elevation of Keyblock

Side Elevation

DATE

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SHADES & SHADOWS PLATE X

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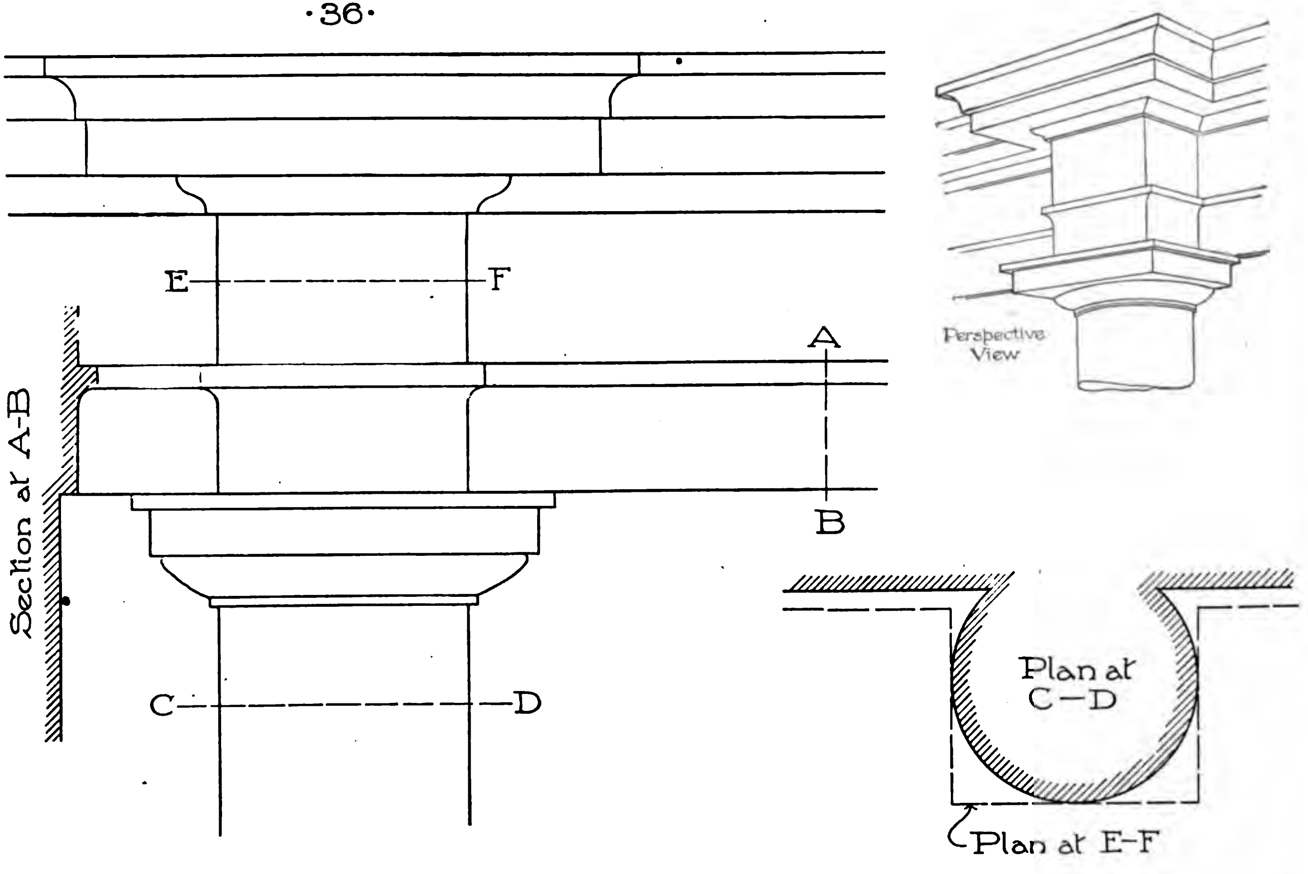

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SHADES & SHADOWS

PLATE XI

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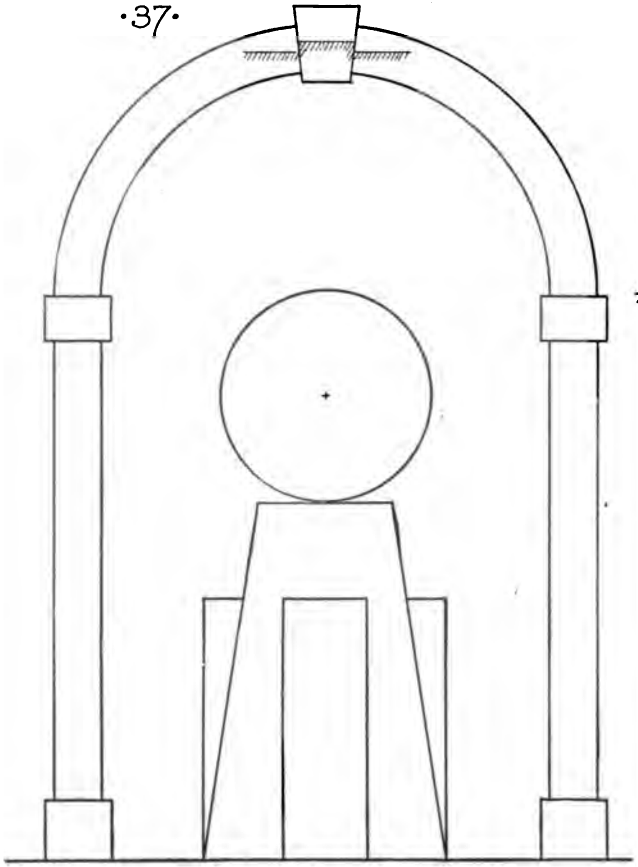

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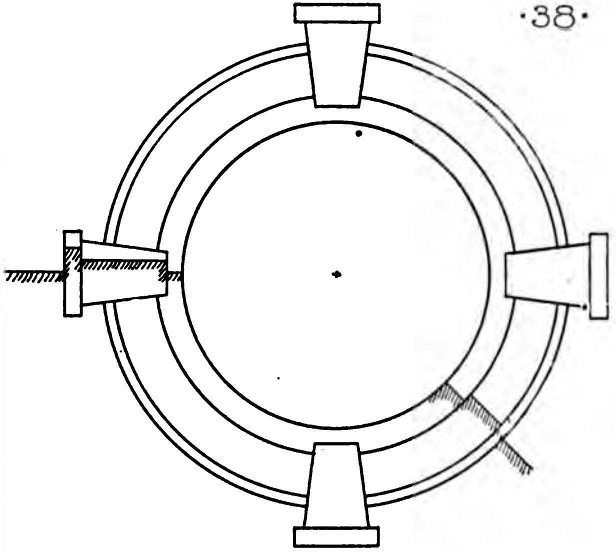

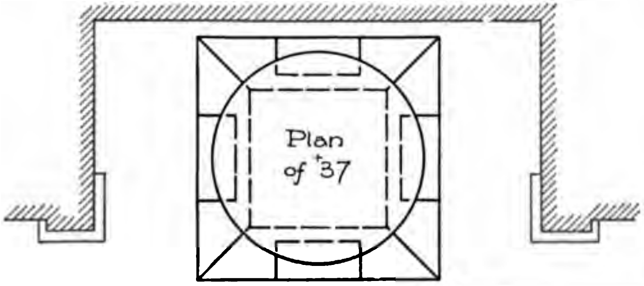

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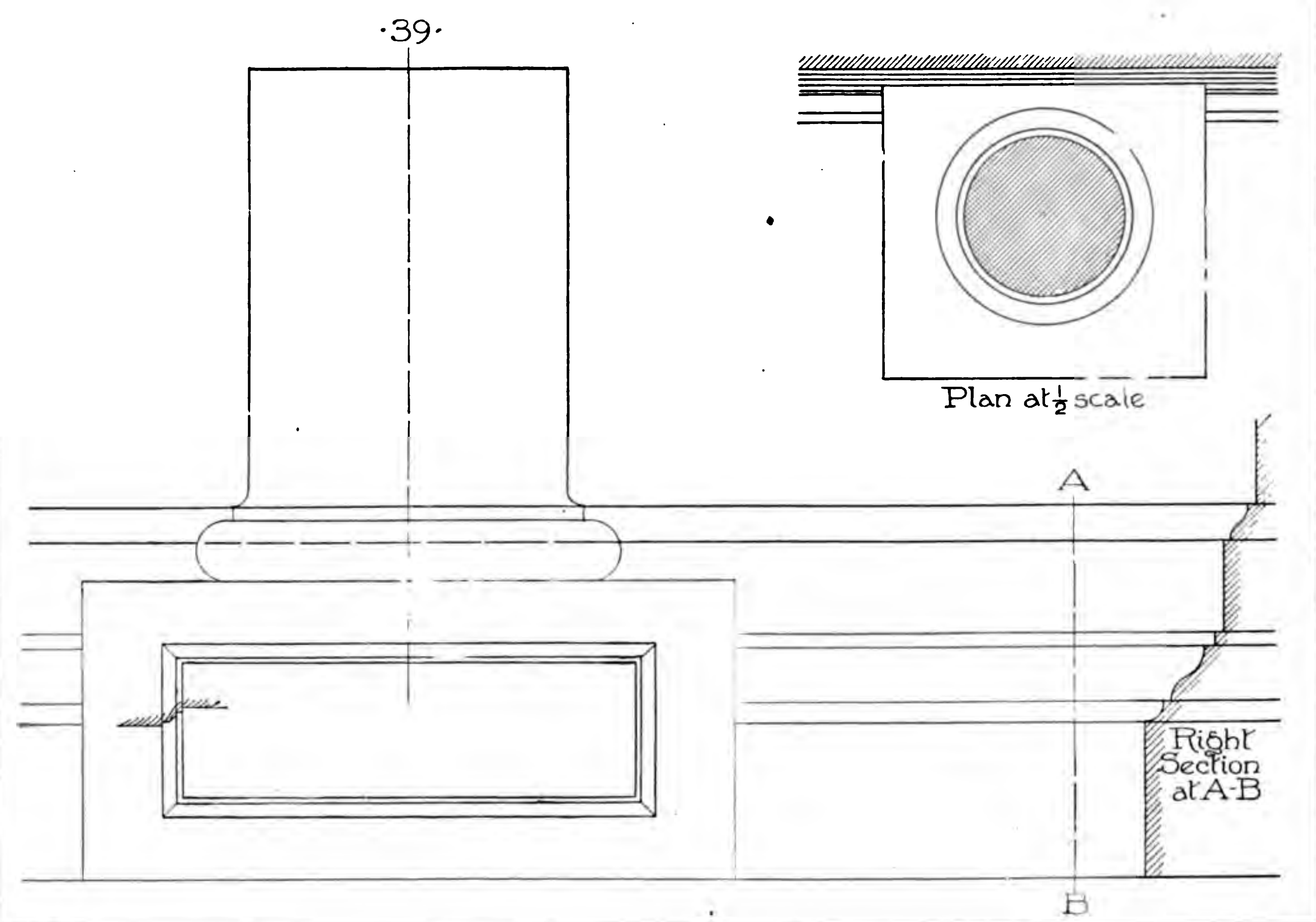
SHADES & SHADOWS PLATE XII



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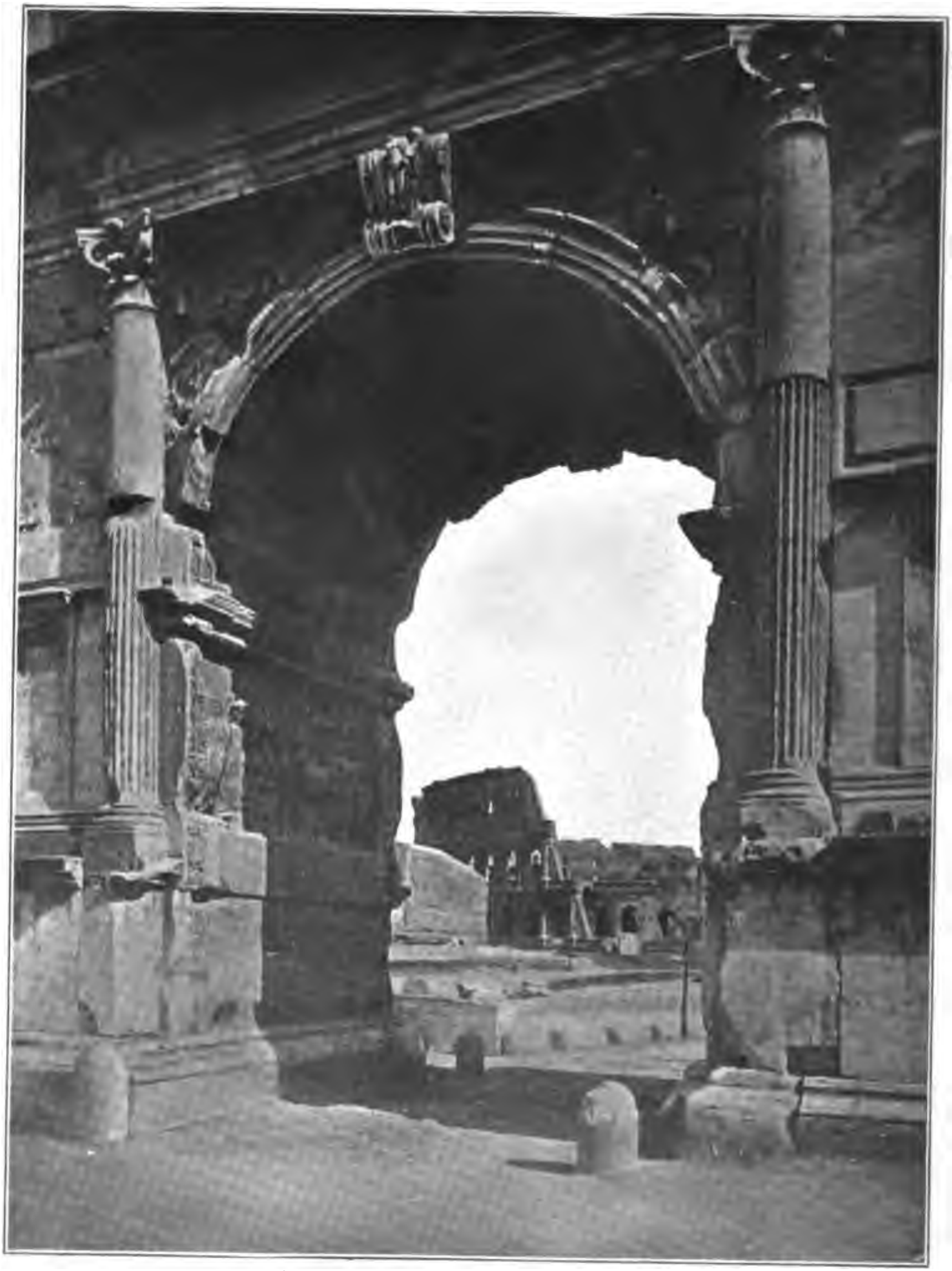


Arch of Titus, Showing View of Colosseum.

STUDY OF THE ORDERS.

THE ROMAN ORDERS.

Introduction. This textbook on the Roman Orders is largely an adaptation and simplification of a work published in 1870, entitled "An Analysis of the Five Orders" by F. Laureys, architect, and professor at the Royal Academy and Industrial School of Brussels. Professor Laureys has taken the standard orders as shown in the plates from the better known work by Vignola, and has further elaborated their system of construction. He has explained in detail many parts of the plates and orders of Vignola, which that authority has left vague or indeterminate, and has generally succeeded in attaining a more distinctive type-form in the instances where he has chosen to deviate from the original. The three order plates from Vignola may be considered as "key-plates" showing the proper relation of the more detailed drawings adapted from the elaborate system of Professor Laureys, and the proper assemblage of the different parts of the order in such a manner as to give a comprehensive idea of the whole.

The included plates from Palladio furnish alternative versions of each of the three orders and are valuable as showing in many instances the authority for the changes which Professor Laureys has chosen to make from Vignola. Vignola and Palladio were practically contemporaneous Italian architects living in the sixteenth century, the first—possibly better described as a thinker and analytic theorist—residing in Rome; while Palladio worked in the north of Italy and, either through better opportunity or a differing temperament, has amply proved by his practices the value of his works.

It must be understood that these so-called Roman orders are not the orders used by the Classic Roman builders in any instance, but are versions made in this sixteenth century from the then-existing buildings and remains of Roman work, and each of these orders was intended to become a "type-form," or composite of the best features of the varying ancient examples. They are, therefore, more distinctively products of the Renaissance and might more appropriately be termed the Renaissance Classic orders, but in contradistinction to the still earlier and radically different creations of artistic Greek workmen, these examples are known as the Roman orders. Indeed, however much they may differ in detail from the Roman originals, they are carried out in as close an approximation to the spirit of Roman work as would be possible at any later date, but differ radically from the spirit and intent of the preceding Greek work, upon which the Romans had in turn founded and developed their application and use of the orders.

Some buildings are the logical outcome of the needs they are designed to serve, or of the nature of the materials used in them; others have been evolved by the artistic genius of different peoples, and have gradually been perfected in the advance and progress of civilization and art. Such buildings possess an æsthetic or artistic character, and are the natural expression of particular peoples at a given stage of their civilization.

The Greeks and the Romans, the most cultivated nations of ancient times, brought their architectural forms to a very high degree of perfection. The destruction of ancient civilization by the Fall of the Roman Empire in the 5th century A. D. and the spread of Christianity, caused the complete disappearance of Greek and Roman architecture during several centuries. This period is called the Middle Ages and lasted until the 15th century, but during this time a new civilization was developing and producing an architecture, which in certain countries (notably in France) attained a very high degree of perfection.

In the 15th century, however, the study of ancient literature brought about an intellectual reaction which led both science and art into sympathy with Greco-Roman antiquity. Architecture then discarded the artistic forms of the Middle Ages and adopted new forms derived from the remains of ancient Rome. This period was called the Renaissance, and from it we may date the academic study of architecture, based on the architecture of Greece and of Rome To the architectural style at this time adopted as a standard for study in the classroom, has been given the designation "Classical," and as the principles of classical architecture are the easiest to formulate and retain, it is most helpful to begin with the study of these. An accurate knowledge of classical architecture is essential to the study of all other styles.

1. Architecture is the art of designing and constructing buildings.

2. The designing of buildings consists in a graphic (or plastic) representation of their intended shapes and sizes.

3. An architect uses mechanical drawing to express his ideas and to record exactly the size and shape of the object represented.

4. In mechanical drawing, the instruments used to draw the straight lines and the curves which express the forms of objects, are, among others, the straight edge, triangle and compass.

5. In general, full straight lines indicate visible edges, and broken or dotted lines indicate relations of different parts, such as the axis or center-line of a street or building or the distance covered by a figured measurement.

6. Horizontal lines are drawn along a T-square whose head rests against the left side of a drawing board. Vertical and sloping lines are drawn against a triangle resting against the T-square. (Fig. 1).

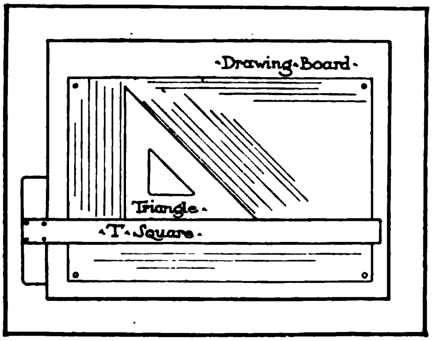


Fig. 1.

7. Two horizontal lines intersecting two vertical lines, all of equal length, form a square. If its opposite corners are connected by straight lines, called diagonals, the intersection of these diagonals gives the center of the square. A horizontal and a vertical line may be drawn through this center, and then, by setting the point of the compass at the center and opening the compass along either of these lines to the sides of the square, a circle may be

drawn which will be exactly inscribed within the square. The square itself will be divided into four small squares, each of which contains a quadrant or quarter circle. (C, plan, Fig. 2.)

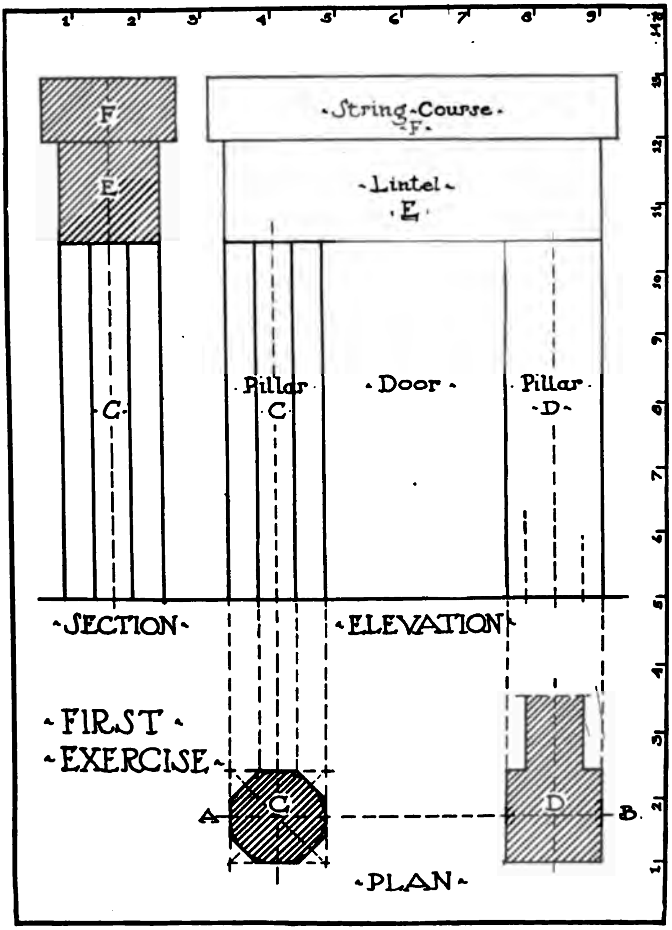


Fig. 2.

8. The circle is divided into 360 parts, which are used for measuring angles or the difference in direction between any two lines that meet in the center of the circle. For convenience, an instrument called a protractor is sometimes used, which consists of a half-circle divided into 180 parts called degrees (°). A vertical line from the center of the circle will cut the curve or circumference at a point 90° above the horizontal, and the diagonals of the square in which the circle is inscribed will divide each angle of 90° into two angles of 45° each.

9. As it is impracticable to draw many objects at their full size, an arbitrary scale is used to enable the drawing to be made at $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{16}$, $\frac{1}{32}$, or some other fraction of its true size. Drawings at the scale of $\frac{1}{4}$ inch to the foot reproduce each dimension of an object at $\frac{1}{48}$ of its true size. The system of drawing things "to scale" enables us to make accurate drawings at any convenient size.

10. To make pictures of objects in such a way as to express accurately the size and shape of every part, three drawings are usually necessary—a plan, a section, and an elevation—the plan to show widths and lengths, the section to show widths and heights, the elevation to show lengths and heights.

11. A drawing looks better when its perpendicular center is half-way across the paper and its bulk placed slightly above the horizontal center of the sheet. Begin then by finding a point in the paper half-way between the sides, and through this center draw a vertical line — the vertical axis of the drawing. Lay out the plan, the elevation, or the sum of the two together with the space between them, so that half the finished work shall be on each side of the vertical axis.

12. In mechanical drawing, it is best to begin by indicating the axes or center lines of objects in plan, section and elevation. On either side of these axes lay out one-half of the width or depth of the objects represented.

13. A pier or pillar is a mass of stone, wood or metal standing on end and used as a support. (Fig. 2, C.)

14. A lintel is a piece of stone, timber, or metal laid flat upon two pillars so as to form an opening or bay. (Fig. 2, E.)

15. A string course is a horizontal band of stone, brick, or other building material projecting beyond the face of a wall. (Fig. 2, F.)

16. The first exercise, Fig. 2, shows two pillars C and D, carrying a lintel E, above which is a string course F. The plan shows the width and the depth of the pillars C and D. It shows that pillar D is square and that pillar C is eight sided (octagonal.)

It also shows that these two pillars are set along a straight line or axis (A-B) having the same direction as two of their sides. The section shows the vertical position, the depth and the height of the pillars, the width and the height of the lintel E, which rests on the pillars so as to line with their face; and last of all the height and the width of the string course F, with its projection beyond the lintel E. The elevation shows the general arrangement of pillars and lintel as seen from an arbitrary viewpoint directly in front. It shows that the two pillars are upright or plumb, indicates the shape of the space between, and gives the length of the lintel and of the string course.

17. All the parts of this drawing have definite relations of size which are called proportions. Each pillar is one unit and a-half wide, one unit and a-half deep and five units and a-half high. The space between the pillars is two and three-quarter units wide and five and one-half high; its width is, therefore, one-half its height.

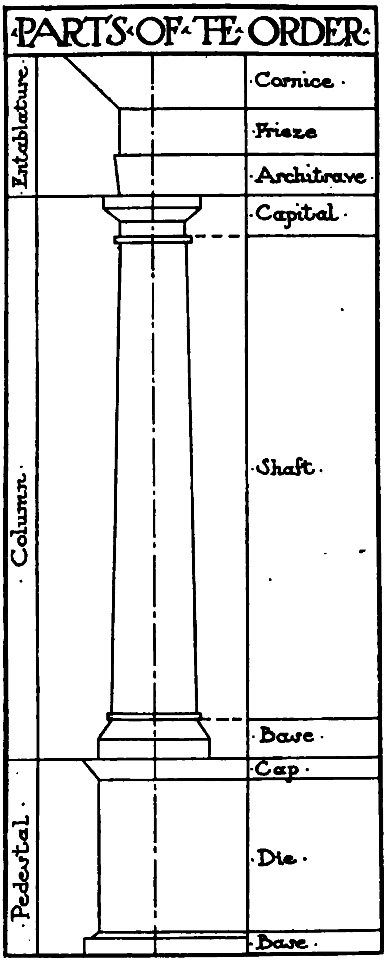


Fig. 3.

18. When a pillar is cylindrical or rounded, it is called a column and is divided into parts, the major part being termed the shaft. (Fig. 3). The shaft is the portion extending between the base and the capital, or between the capital and the support upon which the column rests. The shaft generally rests upon a projecting block or base included as part of the column, and is crowned with another projection called a capital.

19. Columns are connected to one another overhead by a timber or stone called the architrave. Generally there is above the architrave a plain space, called the frieze, lining with the neck of the column below, and above the frieze a projecting mass that completes the whole and is called the cornice. The architrave, frieze, and cornice taken together are called the entablature. A column with an entablature constitute an Order of Architecture.

20. Sometimes an Order of Architecture is set upon a mass of a certain height which is called the pedestal. The pedestal often has a base, and a cornice or crowning member called a cap. The space between the base and the cap is called the die of the pedestal.

21. There are sometimes used at the corners of buildings, or elsewhere against a wall, flat pillars having, like the column, a base and a capital. These pillars are called pilasters.

22. For the sake of elegance and lightness, the shafts of columns and pilasters are generally made smaller at the top than at the bottom. This prevents the shafts from appearing clumsy. They do not, however, taper all the way from the base upward, but only from a point one-third the height of the shaft above the base. Above this point the outline of a column or pilaster shaft is a gentle tapering curve. This swelling curve or taper is called the "entasis" of the column.

23. It must be noted that the diminution of the pilaster is much less than that of the column, and that in some cases the pilaster is of the same width at the neck as at the base. As specifically shown hereafter, there are certain relations between the necks and bases of columns and pilasters of each of the Orders. Occasionally, where a pilaster is used alone upon the corner of a building and not in immediate association with a tapered column, the pilaster shaft is, for obvious reasons, of the same width at the neck as at the base. See plates XXVII and XXVIII.

24. When square pillars carry vaults or arches instead of lintels, the pillars are called piers (Fig. 4). If a support is square or oblong in plan, and its thickness in relation to its height is considerably more than the thickness of a column, it is called a pier even though it carries a lintel. When a pier is topped by a projecting stone or series of mouldings from which an arch springs, this projection is called the impost, and the projecting band or border that is often placed around the edge of the arch is called an archivolt. Piers generally rest upon a base or plinth.

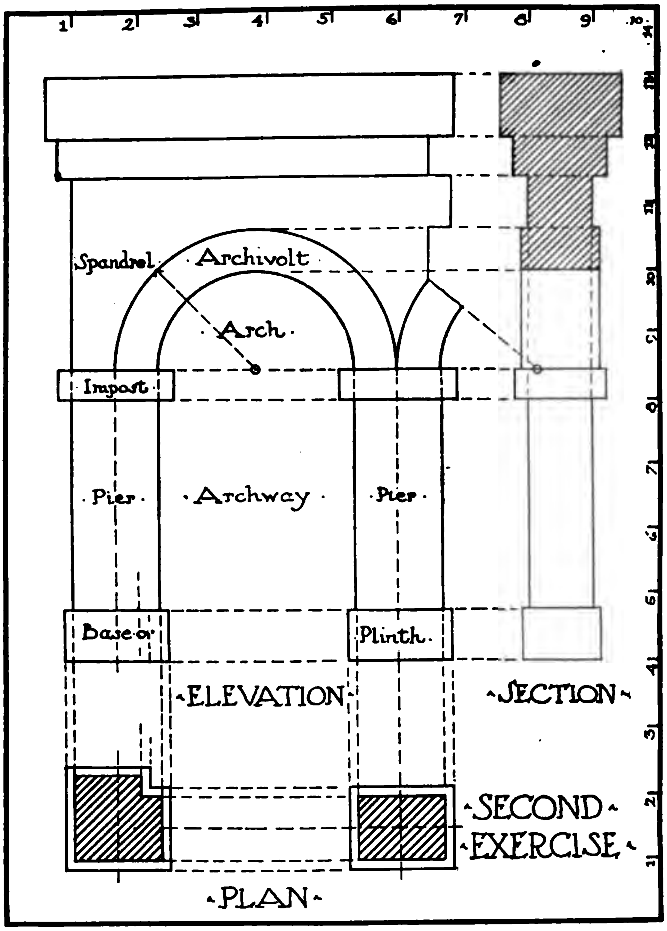
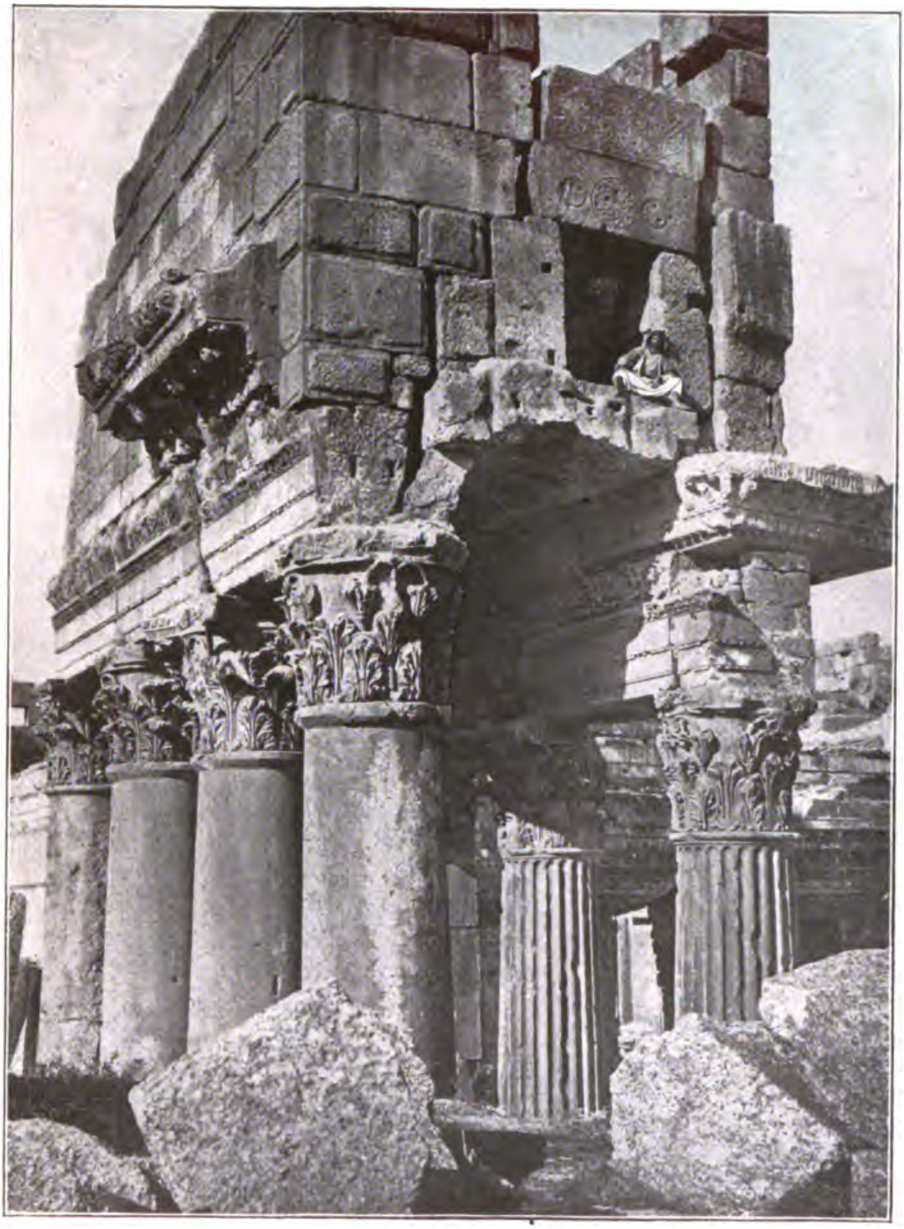


Fig. 4.

25. An arch is a support constructed of separate stones, units, or voussoirs, with its center higher than its two ends, and of an outline which is, in part or entirely, a circle, or a curve laid out from one or more centers. A vault is a continuous arch roofing over a room or passage, whose length is considerably greater than its width. A series of arches in succession opening upon the space covered by a vault, may be called an arcade.



Corinthian Columns.
From the Temple of Jupiter, Baalbec, Syria.

26. Note the distinction between the lintel, a single horizontal member carrying a superimposed weight to the piers by its own strength, and the arch, a curved construction which carries a superincumbent weight by transferring its load to the piers or supports from which it springs, but unlike the lintel, adding a certain lateral "thrust" which the supports must resist.

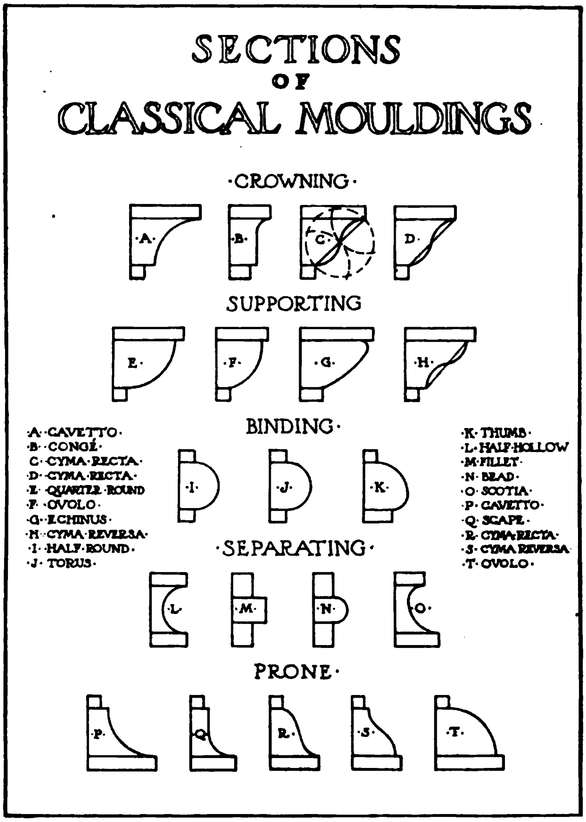


Fig. 5.

27. Bases, capitals, lintels, cornices, imposts, and archivolts are composed of separate members of straight or curved profiles, and these members are called mouldings.

28. Classical mouldings may be divided into five classes: crowning, supporting, binding, separating and prone. The mouldings most frequently used are the quarter round, Fig. 5 (E); the cove or cavetto, (A); the torus or half round, (J); the cyma, (C);

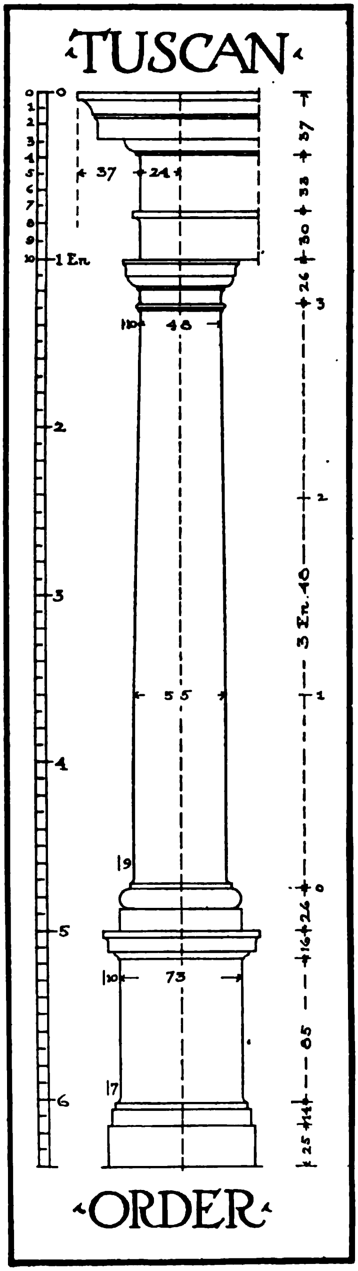


Fig. 6.

the ogee or cyma reversa, (H); and the scotia, (O). The quarter round, cove and torus are simple mouldings whose outline is an arc of a circle; the cyma, ogee and scotia are composite mouldings outlined by the arcs of two or more circles. The fillet (M), while never occupying an important position, is continually used to finish off or to separate the more important mouldings.

29. Classical architecture includes five Orders that differ in the proportions of their columns and in richness of their ornamentation. These Orders have long been called the Tuscan Order, (Fig. 6); Doric Order, Ionic Order, and Corinthian Order, (Plate I) and Composite Order, (Fig. 17). The Doric, Ionic and Corinthian orders are the most important, as they are now in more general use.

30. The five orders have one proportion in common, viz.: the relation of the height of the column to the height of the entablature. The entablature in all five orders is one quarter the column height. The height of the column in any order is therefore the height of four entablatures, and the height of the entablature, although a variable quantity, will always bear a certain relation to the general height of the order.

31. The height of the entablature divided into one hundred

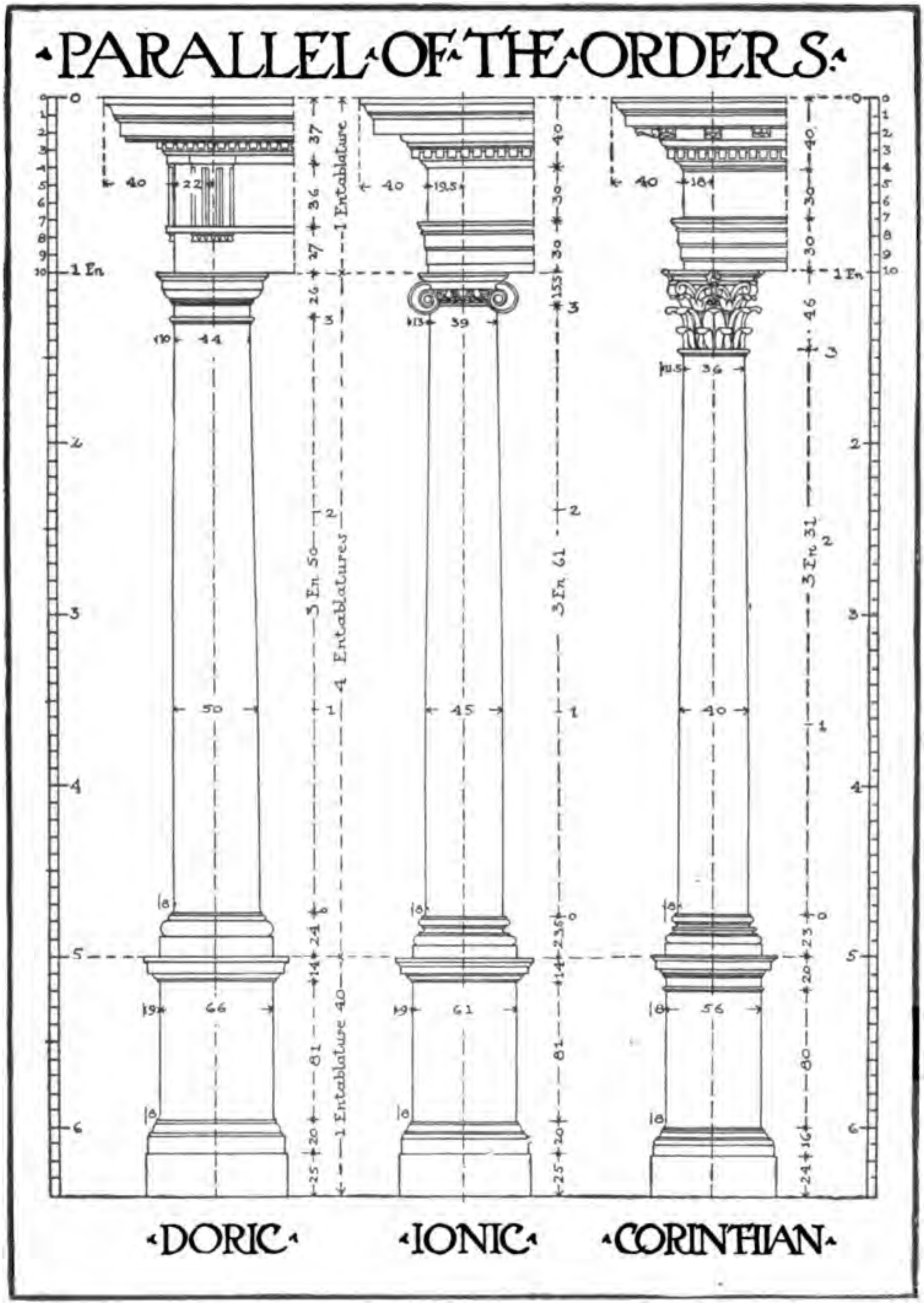


PLATE I.

(A reproduction at small size of Portfolio Plate I.)

parts establishes a scale which may be used in determining the proper proportions of all parts of the order. This scale unit is called the Entablature or "En" and its one hundred parts are, where necessary to show more minute divisions, sub-divided into tenths which are expressed decimally.

32. Another system of measurements which is often used is based upon a unit called the "Module" which is always equal to the radius of the column shaft at the base. This unit, like the "En," may vary in different examples but will always have a definite relation to the order as a whole in any particular case. The "Module" is sometimes subdivided into twelve parts, sometimes into eighteen and sometimes into thirty, depending upon the order considered and the system of measurement to be adopted. It is, therefore, not so reliable a unit as the "En," and the latter will be used in this work. Some of the plates from Vignola and Palladio, however, are drawn according to the "Module" system. It is only necessary to remember that the "Module" is always equal to the semi-diameter at the base of the column.

33. The figured dimensions of a drawing are written along vertical lines in measuring heights, and along horizontal lines in measuring widths. A figured drawing is one whose dimensions are expressed in figures, and the extent covered by each measurement is denoted by dotted measuring lines and by spurs or arrow heads, two of which when meeting form a cross.

34. The most striking difference between the Orders is in the proportions of the columns, whose heights, as already noted, are equal to four entablatures, but whose diameters just above the bases are as follows:

Tuscan order,	55	parts	of the	Entablature	or "En."
Doric order,	50	"	"	"	"
Ionic order,	45	"	"	"	"
Corinthian order	40	"	"	"	"
Composite order	40	"	"	"	"

From the Tuscan to the Corinthian Order the thickness of the column decreases evenly by five parts at each step.

35. The shafts of columns, as we have already seen, are less thick at the capital than at the base. The upper diameter of the columns of the different orders is: for the—

Tuscan	**Order,**	**48**	**parts.**
Doric	"	44	"
Ionic	"	39	"
Corinthian	"	36	"
Composite	"	36	"

36. The Tuscan and Doric columns have one relation in common,—the height of their capitals, which is twenty-six. The cornice in both these orders has a height of thirty-seven.

37. The entablatures of the Ionic, Corinthian and Composite orders have certain general proportions in common, and all the general proportions of Corinthian and Composite columns are identical.

38. When orders are set upon pedestals, the latter must harmonize in their proportions and decoration with the orders carried by them. The height, however, is variable, being generally prescribed by the practical requirements of each building. A good average height is 1 En 40 parts or 140 parts. Although pedestals are not component parts of the orders it is convenient to call them according to their characteristics, Tuscan pedestals, Doric pedestals, Ionic pedestals, etc., as the case may be. The several orders differ in the complexity of their mouldings and the richness of their ornamentation.

TUSCAN ORDER.

39. Although it has been deemed best to restrict this textbook to a consideration of the three Roman orders termed the Doric, Ionic and Corinthian, the simpler Tuscan Order is shown sufficiently in detail to enable the student to use it in the exercises as required. The simplicity of its mouldings and the comparatively few lines required to express its component parts seem especially to fit this order for the earlier required drawings. The general proportions of the Tuscan Order are shown in Fig. 6, while the details may be more carefully studied in the full page drawing, Plate II

40. The shaft of the column has at its lower extremity a projecting member called the listel, surmounted by a curved member called the congé or cove, which is itself a continuation of the outline of the column shaft. The listel rests directly upon the

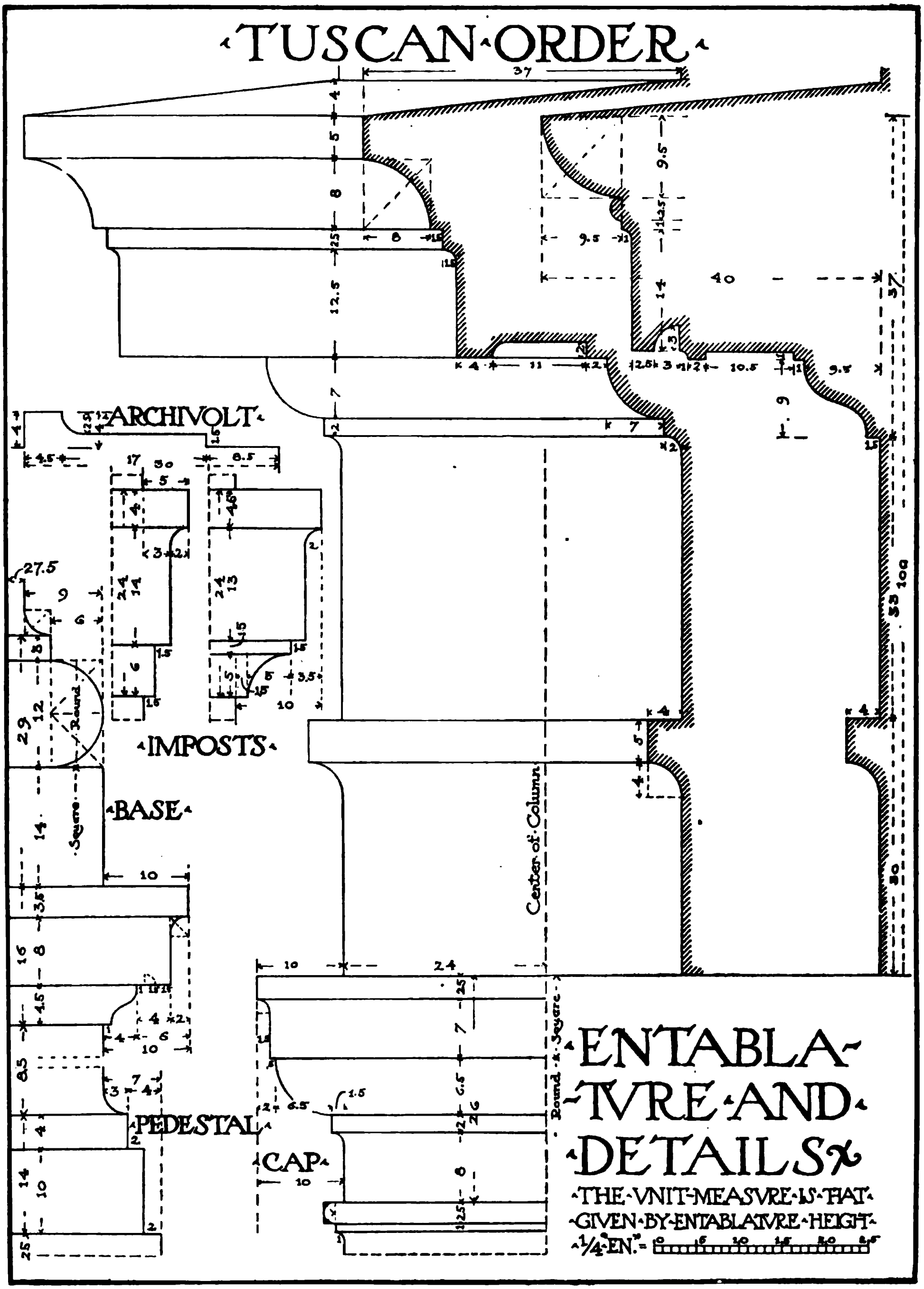


PLATE II.
(A reproduction at small size of Portfolio Plate II.)

base and is three parts in height and the same in projection, therefore the surmounting congé is in outline just a quarter of a circle.

41. The height of the base without the listel is 26 parts, divided between the plinth, which is 14 and the torus which is 12. Since a torus has the form of a semi-circle, its projection is one-half the height, that is to say six, which—with the projection of the listel—makes the total projection of the base beyond the lower part of the shaft nine parts.

42. The projection of the base determines the width of the die of the pedestal whose face corresponds to the face of the plinth above, and it is from this face that the projections of its cap and base are measured. These projections and moulding sections are shown at the left of the drawing in Plate II.

43. The shaft of the column is terminated below the capital by a moulding composed of a congé, a fillet, and a small torus which is called a bead; these mouldings taken together are termed the astragal.

44. The Tuscan capital is very simple, and is composed of three principal parts. Above the astragal occurs the necking, 8 parts in height and ending in a congé. Then comes a fillet 2 parts high. Above this is the quarter-round 6.5 parts in height and of equal projection. The upper part of the capital is composed of the abacus, ending in a congé and fillet, the whole 9.5 parts high. The abacus is, like the plinth of the base, square in plan. The total projection of the upper edge of the abacus from the face of the necking is 10 parts.

45. The architrave is composed of a single face, terminated by a cove and a listel. The total height of the architrave is thirty parts, of which twenty-five are given to the face and cove, and five to the listel. The projection of the listel is four parts.

46. The frieze of the Tuscan Order is thirty-three parts in height, and is terminated at the top by a congé.

47. The cornice is composed of three principal parts: the quarter-round, the corona and the cavetto. To each of these parts is also given a fillet or listel to finish or separate it from the adjacent mouldings. An alternative entablature is shown upon the same plate, lining with the one just described.

48. On this plate (II) are also shown the details of two imposts and an archivolt which may be employed in the decorated arcades of the Tuscan Order. The imposts are twenty-four parts in height, and the archivolt is thirty parts wide.

DORIC ORDER.

49. There are two styles of the Doric Order, the Denticular Order and the Mutular Order. The difference between these two styles is purely decorative and will be explained in the course of this analysis.

50. The Doric column, more elegant than that of the Tuscan Order, is sometimes fluted with segmental channels, the intersection of which forms a sharp raised edge or "arris." These channels are always twenty in number, and are so placed that one is always seen in the center of the column on each of its four faces.

51. To draw a column with channels, it is necessary to make a plan just above the base, that is to say, at its greatest diameter, and another at its smallest diameter or at the necking of the column. (Plate III.) Having divided the semi-circumference into twenty different parts, and having determined the radius through each point of division, draw a chord of the arc comprising two of these divisions; and with an opening of the compass equal to one-half of this chord, and from the point where it intersects the radius which divides it into two parts, draw a semicircle outside of the circumference of the column. The summit of this semi-circle will be the center of the arc of the circle that forms the channel. By taking the corresponding point on each alternate radius all the channels may be drawn with the same opening of the compass. As a result of this method, the arc of the Doric channel is exactly a quarter circle.

52. The head or upper part of each channel is a semicircle, while the foot rests on a plane inclined at forty-five degrees. In drawing a channeled column there is but one channel seen in direct front elevation, the others follow the curvature of the shaft, and are drawn according to their positions on the plan. They form at the upper and lower extremities different curves which can be obtained only by projecting the proper points.

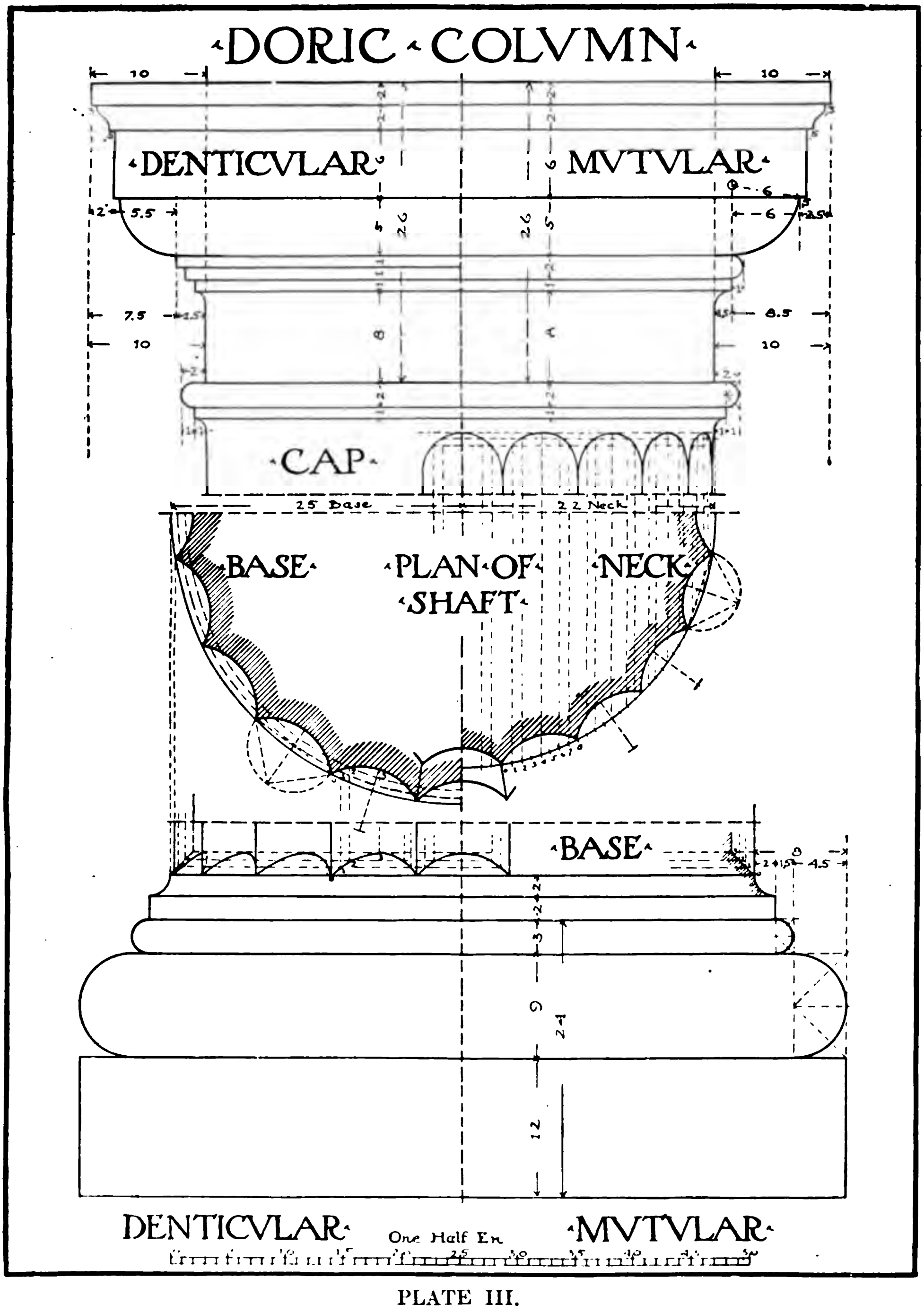


PLATE III.
(A reproduction at small size of Portfolio Plate III.)

Thus, to obtain the curves formed by the heads of the channels draw (in elevation) the semi-circle forming the head of the central channel, and divide the plan of each one into eight equal parts. Now project upward the points of division on the plan of this central channel by vertical lines drawn to intersect the semi-circle in elevation. From these points of intersection, draw horizontals which will pass through all the other channels. Then draw verticals from the plan of each channel, as has already been done with the central one, and at the intersection of these verticals with the respective horizontal lines, points of projection may be marked by means of which one may describe the various curves.

For the foot of the channels the section must be used to establish the points of projection by dividing the inclined plane into three equal parts, and from each of these points of division, horizontals passing through all the channels may be drawn; then, dividing the depth of the channel on the plan into three equal parts, one may draw from the center of the column, two circles passing through all the channels. At the points where these circles intersect the outlines of the several channels, points are found in plan which may be projected to the horizontals of the elevation. Through these points may be drawn the several curves of the channel footings.

53. This plate shows also the details of the capitals and bases of the two Doric Orders. The left half shows the Denticular and the right half the Mutular Order. The capitals have the general characteristics of the Tuscan capital, but they have several differences of detail. For example, the abacus is enriched by a small cyma-reversa with a listel or fillet; while the necking is separated from the quarter-round by three "annulets" in the denticular, and by an astragal in the mutular order.

The height of the Doric capital is the same as that of the Tuscan Order, twenty-six, divided thus: the necking eight, the annulets or astragal three, the quarter-round five, the abacus six, the cyma-reversa two, and the listel two; the total projection of these members is ten, of which two is the projection of the cyma-reversa, .5 is the projection of the abacus beyond the quarter-round, five for the quarter-round in the denticular order, and 2.5 for the three annulets.

The quarter-round in the mutular order is of the same height as in the denticular but it has a projection of six, and is drawn with a radius of six, and the congé of the astragal has a projection of one and five-tenths. The shaft of the column terminates below the necking of the capital by an astragal of three parts, of which one is for the annulet, and two for the bead or ring; the congé has a projection of one.

Sometimes, in order to give increased richness to the capital, certain mouldings are carved. The cyma-reversa of the abacus is adorned with the leaf and tongue ornament, the quarter-round with eggs and darts, and the "baguette" or bead with beads and reels.

54. The Doric base is twenty-four parts in height, divided among the plinth of twelve, the torus of nine, and a bead or ring of three; the fillet below the congé of the column is two in height. The projection of the base is eight, comprising the congé of the column, which is two, the bead 1.5, and the torus 4.5.

55. The Doric entablatures are shown in Plates IV and V. The architraves have a characteristic ornament which consists of a row of small truncated cones (or pyramids) called "guttae," attached below the listel of the architrave to a small band called the reglet or taenia. Their position corresponds to the channeled parts of the frieze above, which are called the triglyphs. Notice that the denticular architrave is composed of a single band crowned by a listel, while the mutular has two bands, of which the upper projects beyond the one that rests upon the capital. These bands are designated by the name fascia or "facure."

Both styles of Doric architraves are twenty-seven parts in height, of which four are given to the listel.

The lower band of the mutular Doric architrave is nine parts in height; the height of the guttae is three, of the reglet or "taenia" one. The denticular style has but one projection, that of the listel, which is three. The mutular has a projection of four, because of the added projection of the second fascia which is one. The guttae are spaced four parts from center to center; their lower width is three and the upper width two. The face of the taenia is parallel to the slope of the guttae. The projection of the guttae from the face of the architrave is 2.5 on the bottom, and two at the top.

56. The frieze of the Doric Order is thirty-six parts in height

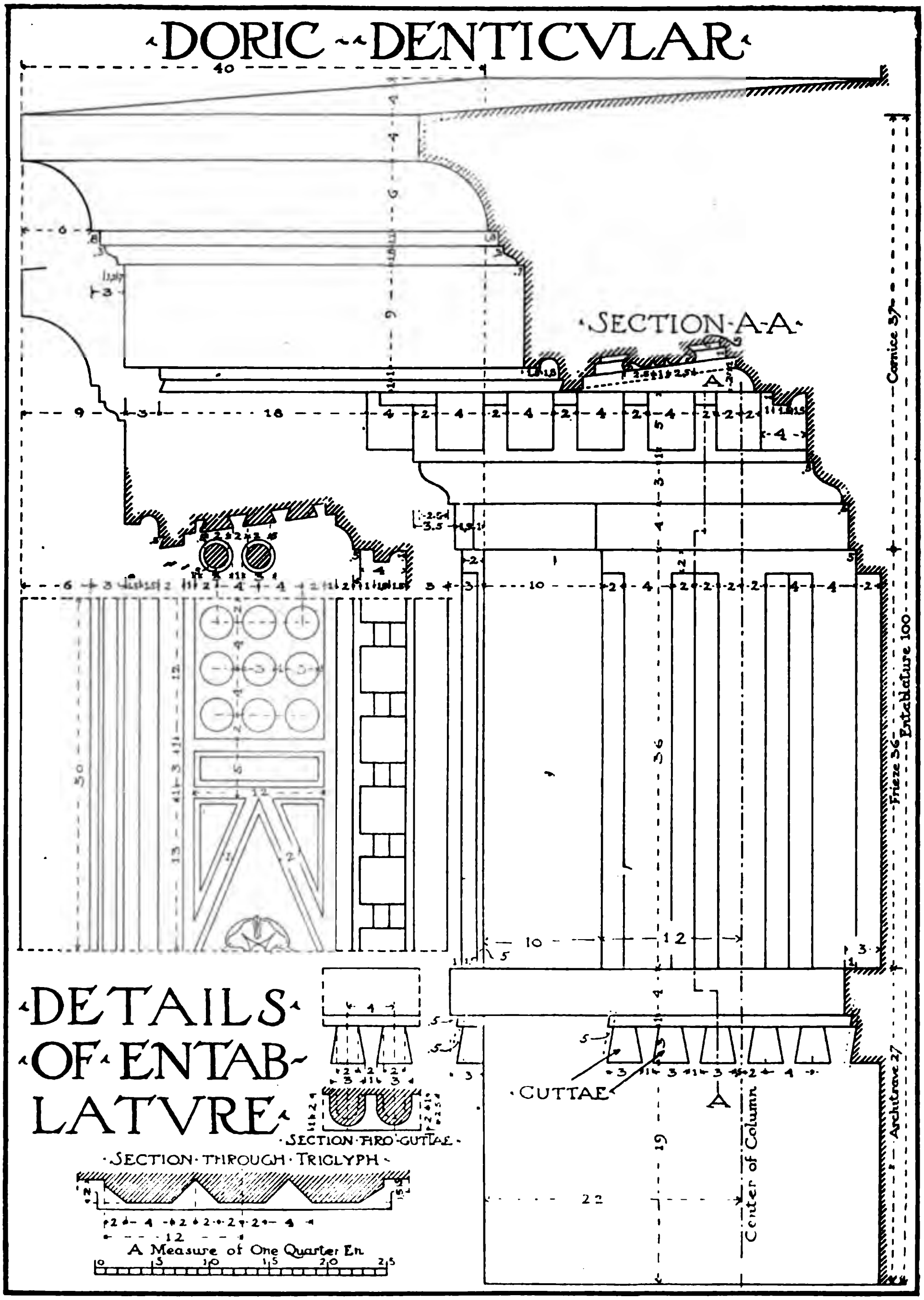


PLATE IV.
(A reproduction at small size of Portfolio Plate IV.)

and is distinguished by its triglyphs, which are apparently the extremities of beams, forming on the frieze a slight projection of two parts, and spaced at regular intervals. The name comes from the triangular channels with which they are ornamented. The detail of this ornament as well as of the dependant guttae is clearly shown in Fig. 7.

57. The cornice of the denticular Doric Order is thirty-seven parts in height and its projection is forty. It is composed first, of a band four parts in height and one in projection, forming a slight projection of .5 over each triglyph; second, a cyma-reversa of three in height and 2.5 in projection, placed with a projection of five-tenths over the head of the triglyph; third, a band six in height and five-tenths in projection over the cyma-reversa; against this band are placed small blocks, five parts in height and four in width, with a space of two between them, which are called dentils; fourth, a corona eleven parts in height comprising two fillets, of one part each which are seen in profile on the section AA and which, with the drip, are intended to carry off the rain water; fifth, a cyma-

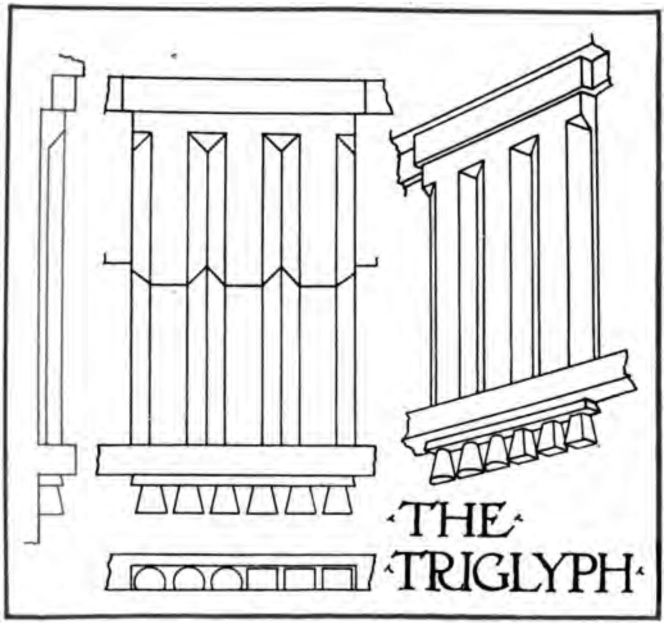


Fig. 7.

reversa of 1.8 surmounted by a fillet of 1.2 and the whole projecting 2.2; sixth, a cavetto of six, and six in projection; seventh, a listel of four crowning the cavetto.

58. The two sections show that the dentils are surmounted under the corona by a cavetto of two in height, having a projection of two in which is included the offsetting projection of .5. This cavetto causes the soffit or lower face of the corona to be inclined two parts. This soffit is divided into panels of various forms corresponding to the divisions of the frieze, as will be seen in Fig. 9. Those panels which correspond to the triglyphs are ornamented by round guttae, the position of which is determined by the edges of the channels. The guttae are three parts in diameter at the lower face and two at their summit; they are one in height and are placed in three rows spaced four from center to center. The other panels are divided into lozenges and triangles and are sometimes ornamented with rosettes or other devices.

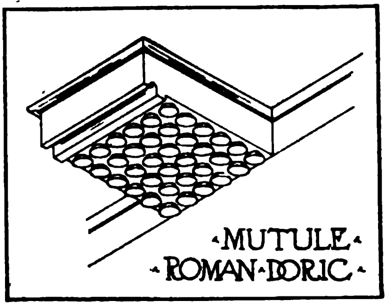


Fig. 8.

59. The frieze of the mutular order is distinguished only by a slight difference in the channels of the triglyph. The channels on the edges are eased off into a curve at the top, while the others form re-entering angles.

The cornice is noticeable for the projecting blocks which depend from the corona and which are called mutules (Fig. 8). This cornice (Plate V) has the same height as the preceding one (Plate IV), but it differs in its projection, which is forty-two. The height is divided in the following manner: the band above the triglyph four, the fillet 1.5, the quarter round three and five-tenths, mutules six and five-tenths, cyma-reversa one and five-tenths, the corona eight, cyma-reversa one and eight-tenths, fillet one and two-tenths, cyma-recta six, and the listel three. The projection is divided as follows: the thickness of the triglyph two, band and listel one, quarter-round three and five-tenths, the fascia five-tenths, mutules twenty-four and five-tenths, corona two and

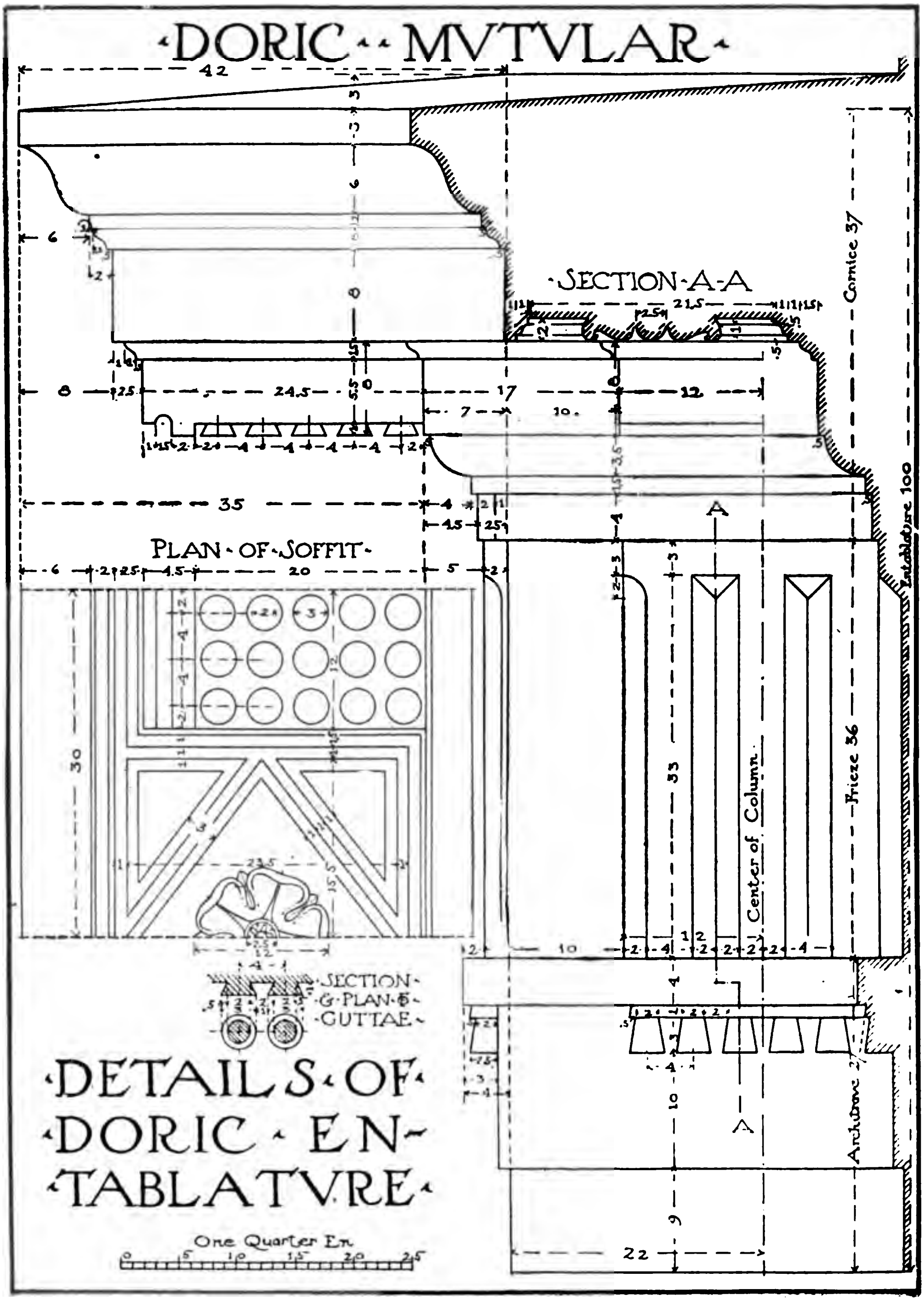


PLATE V.
(A reproduction at small size of Portfolio Plate V.)

five-tenths, fillet projection with cyma reversa two, and the cyma-recta six.

The mutules have a face five and five-tenths in height and form a profile composed of a square of one, a drip of one and five-tenths, and a reglet of two. The lower face of the mutules in Plate V is decorated with five rows of guttae, six in a row. As the mutules correspond in their position and in their width to the triglyphs, so the divisions of the guttae correspond with the edges of the channels of the triglyphs.

60. In the Doric Order the axes of columns and pilasters always correspond to the axes of the triglyphs above them. The upper semi-diameter of the column being twenty-two, the axis of the first triglyph is placed at twenty-two from the angle. The triglyphs are twenty-four in width, and the spaces which separate them are thirty-six. These spaces are exactly square, having a width equal to the height of the frieze, and are called "metopes." The mutules are of the same width as the triglyphs, twenty-four, and are placed on the same axes. Sometimes the metopes are decorated with objects of sculpture whose character is suggested by the character of the edifice. (Plates VIII and IX.)

61. The under part of the corona, or "soffit" of the Doric cornice is divided like the frieze, its divisions corresponding to the triglyphs and the metopes, as we have already seen. The arrangement of the soffit at the angle must be carefully observed:—in the denticular cornice, Fig. 9, there is included in the corner a division which corresponds to the width of the metope: first, a division of five; second, a division of 13; third, another division of five; and finally—at the angle—a square of twelve and a fillet of one. These parts are decorated with panels where sometimes are placed rosettes, winged thunder bolts, or other ornaments in accordance with the character of the edifice. In the soffit of the mutular cornice (Plate IX) there is at the angle a square of twenty-three and five-tenths, decorated with a panel which may be filled with sculpture, such as the winged thunder-bolt. The space between this panel and the mutule is ornamented with lozenge shaped panel, in which is a rosette.

62. The cymatium or cap of the pedestal (Plate VI) is fourteen parts high, of which the divisions are: a fillet of one, quarter-round of three, corona of seven, and listel of three. Its projection is nine, of which four is the projection of the congé and quarter-round, three and five-tenths of the corona, and one and five-tenths of the listel.

The base of the pedestal is forty-five in height, divided among a first plinth twenty-five, second plinth ten, listel three, cyma-reversa five, and fillet two. The projection of the base is eight, of which one is for the first plinth, one for the second plinth, four for the cyma-reversa, and two for the congé. The die of the pedestal is eighty-one parts high and its sides are in plane with the faces of the plinth of the column base.

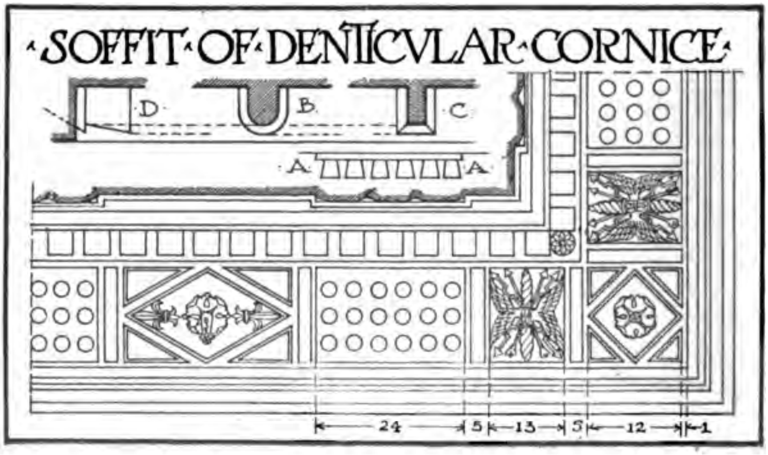


Fig. 9.

63. The impost is twenty-five in height; it is composed of an astragal of three, a necking of seven, a fillet of one, a quarter-round of three, a corona of eight, and a listel of three.

The projection of the impost is eight; for the quarter-round and fillet four, for the corona two and five-tenths, and for the listel one and five-tenths. The astragal projects two. The archivolt is thirty in height; it is composed of a first band nine, second band

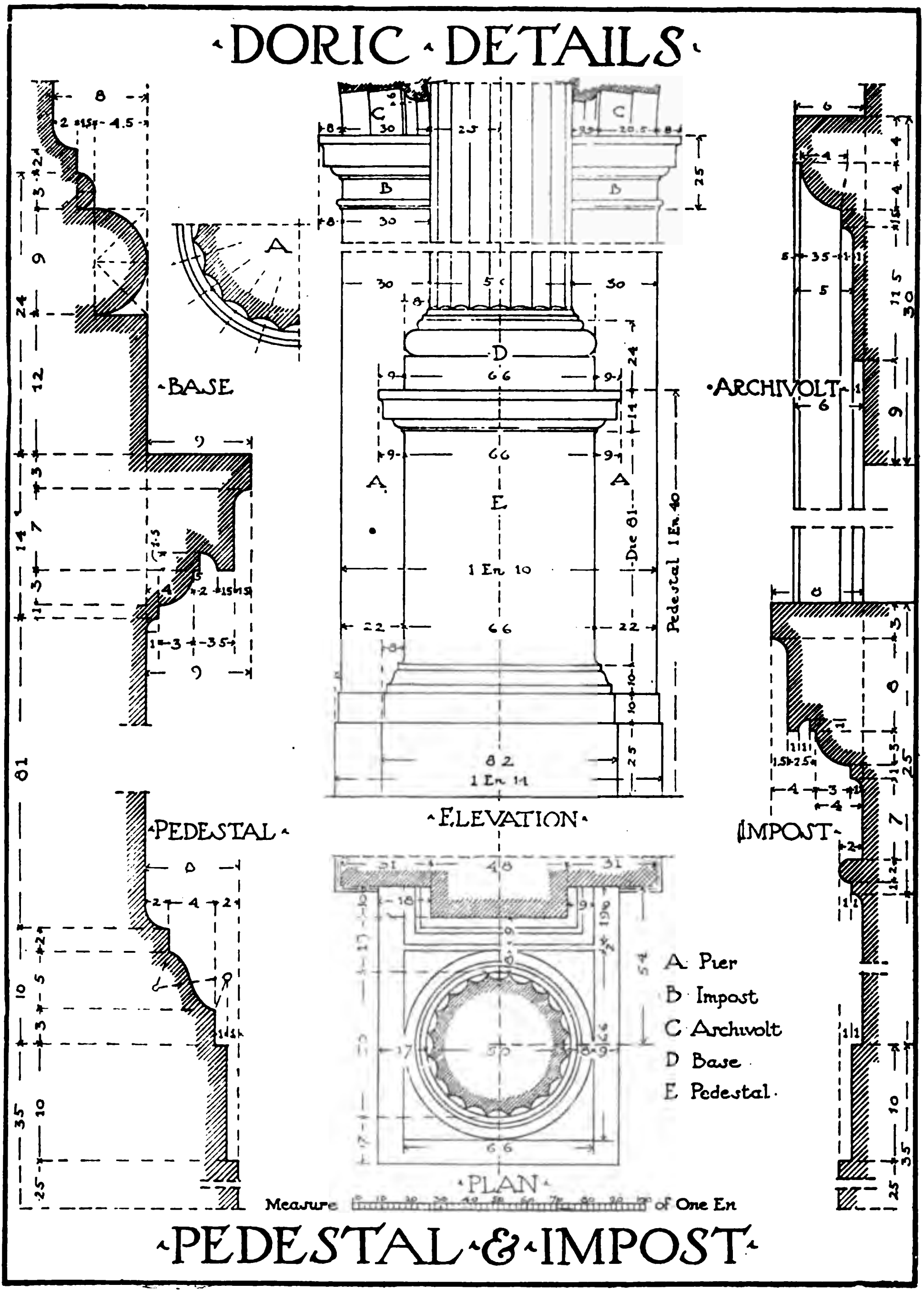


PLATE VI.
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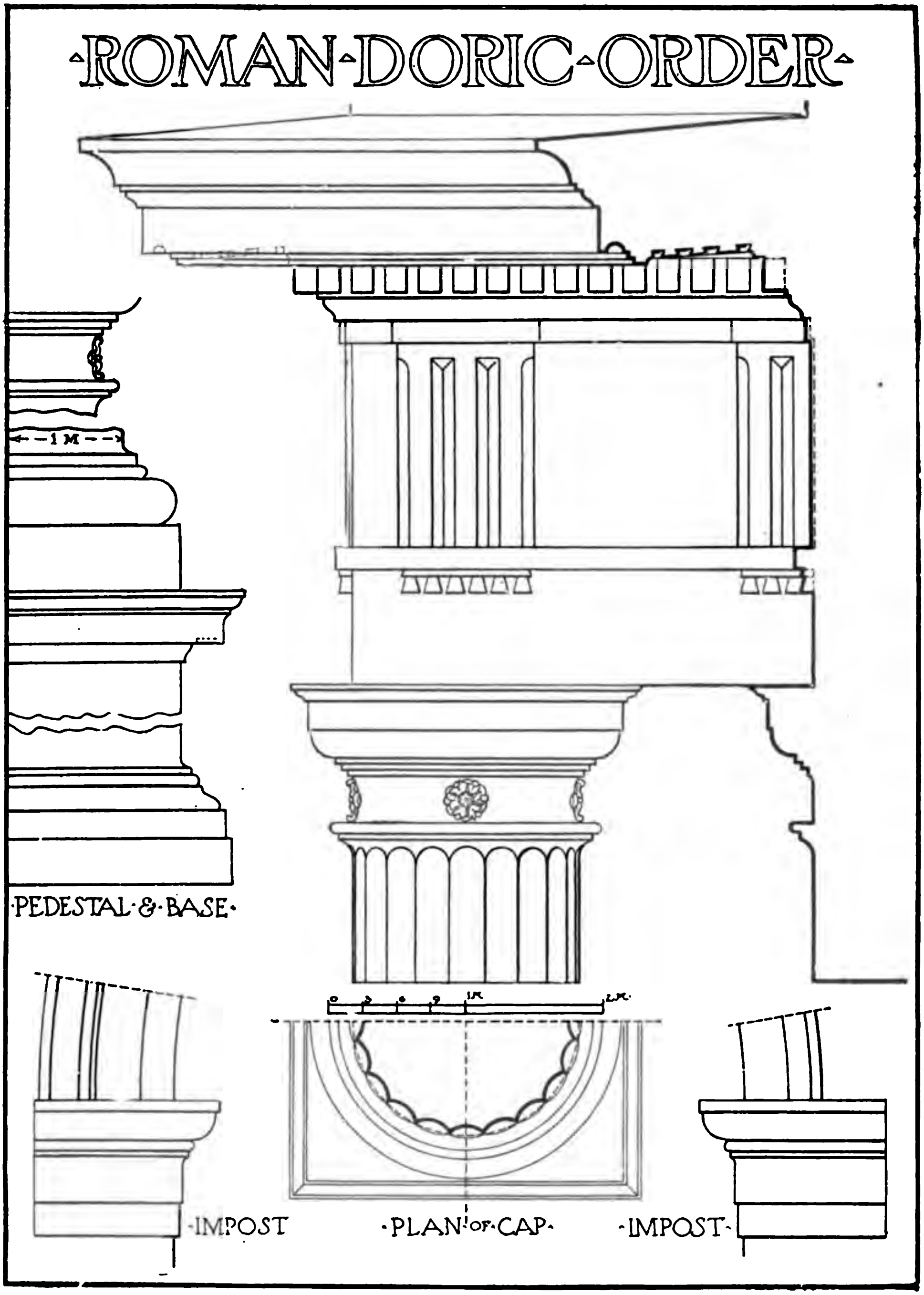

PLATE VII.

(A reproduction at small size of Portfolio Plate VII.)

eleven and five-tenths, fillet one and five-tenths, quarter-round four, and listel four.

The projection of the archivolt is six; second band one, fillet one, quarter round three and five-tenths, and listel five-tenths.

64. The width of the Doric pilaster in proportion to the column is shown in Fig. 10. The lower diameter of the Doric column being fifty and its upper diameter forty-four, the difference is six, which is divided into three equal parts, of which one is taken for the difference in width between the neck and base of the pilaster, forty-eight being the width at the base and forty-six at the bottom of the cap.

The difference of projection of the bases is made up in the congé which projects two for the column and three for the pilaster.

The difference in the projection of the caps is made up in the three annulets and the quarter-round of the denticular capital and in the astragal and quarter round of the mutular capital.

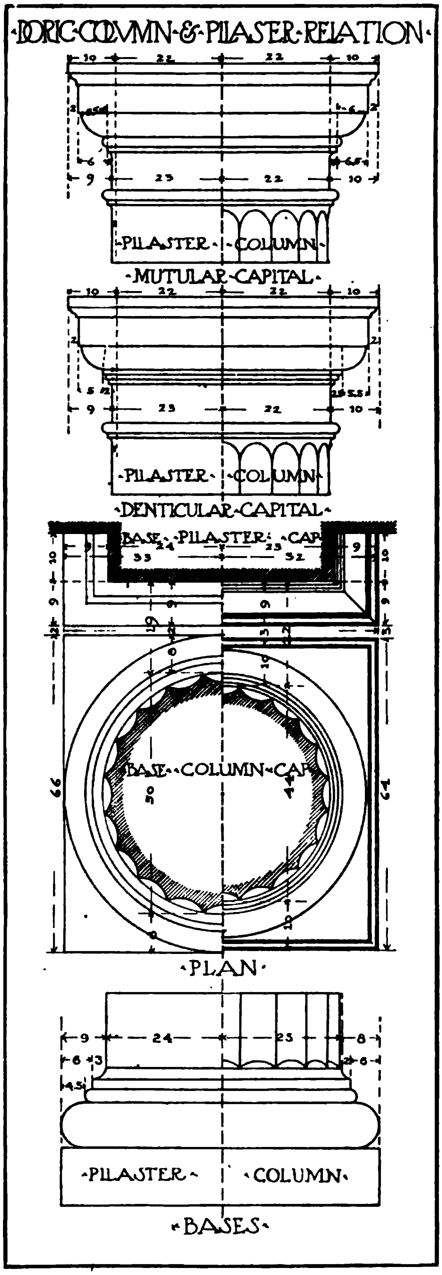

Fig. 10.

THE IONIC ORDER.

65. The Ionic Order is distinguished principally by the form of its capital, of which the spiral scrolls, called volutes (Plate X) are the most important and determining characteristic.

66. The abacus of the Ionic capital is square; it projects six parts from the lower face of the architrave or from the upper diameter of the shaft of the column, is four parts in height and is composed of a fillet of two parts and a cyma-reversa of two. The fillet also has a projection of two. The upper face of the abacus forms a square of fifty-one on each side, and the lower face a square of forty-seven; the volutes grow from beneath the abacus on opposite sides; the catheti, which are the vertical axes or center lines of the volutes, are placed a distance of twenty-one from the axis of the column, or project one and five-tenths beyond its upper diameter. The height of the volute being twenty, the three following dimensions may be laid out on the catheti below the abacus; ten for the volute above the eye, two and five-tenths for the diameter of the eye, and seven and five-tenths for the lower part of the volute. The volute may then be drawn.

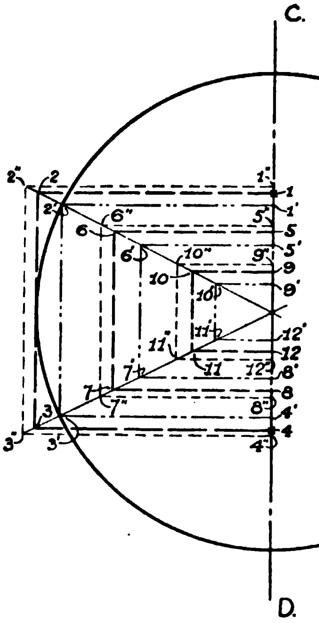

Fig. 11.

67. The spiral or volute is composed of twelve quarter circles drawn from twelve different centres, which may be located in the following manner. Having established, on a vertical line called the "cathetus," the height of the volute, twenty parts, it is divided into eight equal portions. The divisions are marked 1, 2, 3, 4, 5, 6, 7 and 8, commencing at the lower edge. Mark the middle

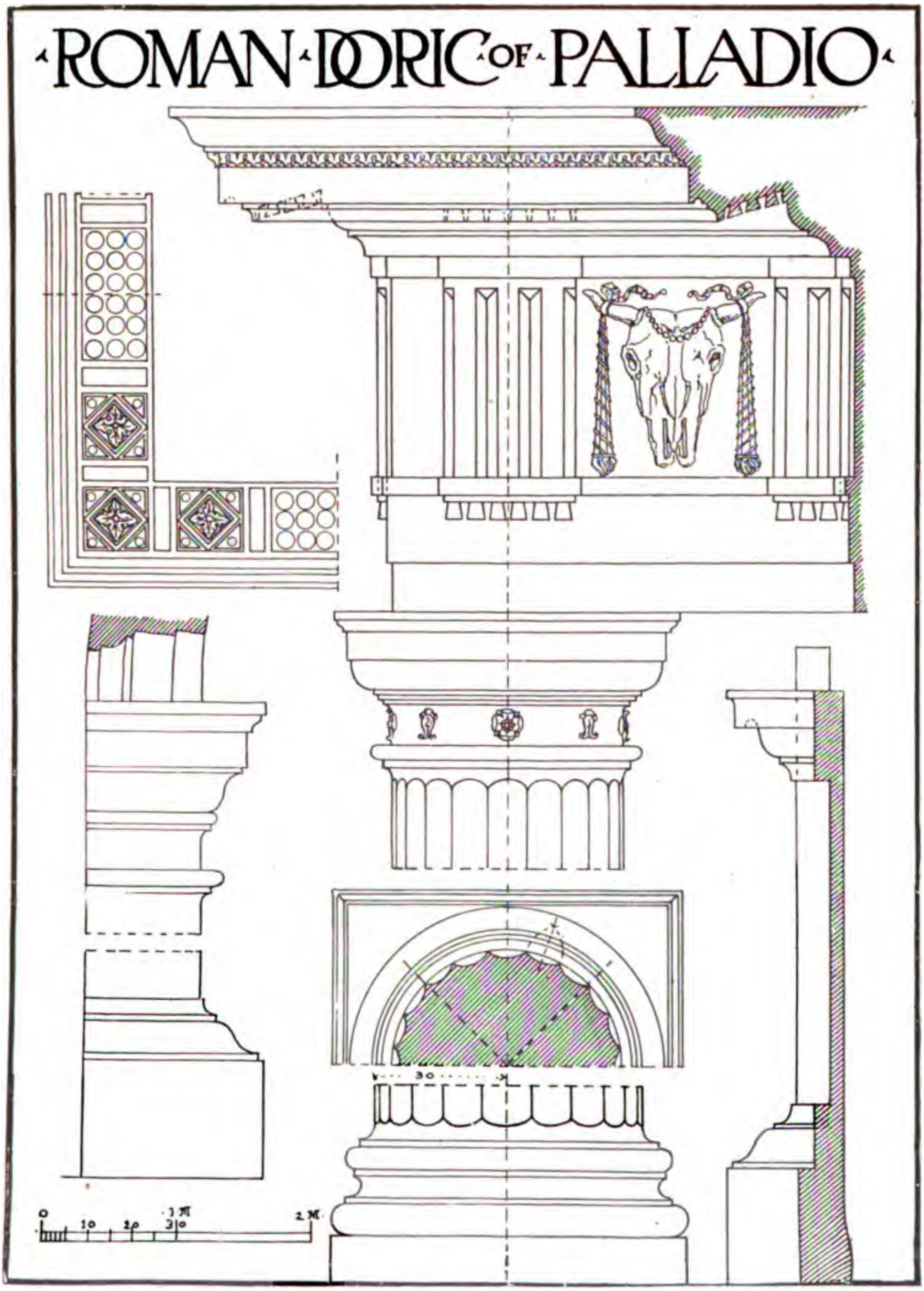

PLATE VIII.
(A reproduction at small size of Portfolio Plate VIII.)

of the space included between the points 3 and 4, and draw through this central point a horizontal line. Taking this same point for the center, draw with a radius of one-half part, a circle which will be the eye of the volute. This eye is shown enlarged in Fig. 11. Divide into two equal parts the two radii of the eye which coincide with the cathetus, C–D giving the points 1 and 4, and here construct a square of 1, 2, 3, and 4, in the direction in which the mass of the volute is to be drawn, in this case on the left of the cathetus. The side of this square which coincides with the cathetus being divided into six equal parts, the other two squares —five, six, seven, eight, and nine, ten, eleven, twelve—may be drawn. In this manner are obtained twelve center points at the corners of the squares, numbered from 1 to 12 from which are drawn the twelve quarter circles that constitute the exterior spiral. Horizontal and vertical lines from these twelve centres determine the limits of the twelve quarter circles.

68. In order to trace the second spiral which forms the inner edge of the fillet of the volute, divide into three parts on the cathetus (Plate X) the space included between the first and the second revolution, that is to say, the distance between the points six and eight. One-third of this distance 6-8 will be the width of the fillet. To find the twelve centers for the second spiral, draw three new squares of which the height and position are determined by dividing into thirds the space between the squares of the first spiral so that the new square 1′, 2′, 3′, 4′, (Fig. 11) shall be within the square 1, 2, 3, 4, by just ⅓ the distance from 1 to 5 and from 4 to 8. The new squares 5′, 6′, 7′, 8′, and 9′, 10′, 11′, 12′, will have corresponding relations to squares 5, 6, 7, 8, and 9, 10, 11, 12, respectively. From the points 1′ to 12′ inclusive, the second spiral may be drawn in the same manner as the first.

69. For the outer fillet, which appears below the abacus and beyond the cathetus, (Plate X) find four center points by constructing a new square larger than the square 1, 2, 3, 4, (Fig. 11). This is determined by taking on the cathetus C–D, half of the distance from the point 1 to the point 1′, and measuring this distance outside of the point 1 to the point 1″, from which 2″, 3″, 4″, etc., can be readily drawn.

70. The space included between the lower part of the abacus and the first complete revolution of the volute forms a flat band which ties together the two volute faces of the capital, and this band is set back two and five-tenths from the projection of the abacus. (See section through side of capital.) The fillet disappears in this face by a quarter of a circle drawn from the point six on the cathetus. The space between the lower line of this face and the horizontal line passing through the center of the volute eye is taken up by a quarter-round drawn with a radius of six and projecting four and five-tenths from the face of the volutes or eight from the outside of the shaft, as may be seen at B in the section on the right of the drawing of the "Side of the Capital." This moulding follows the circular plan of the shaft and is ordinarily decorated with eggs and darts. Below this quarter-round is found an astragal which unites the capital with the shaft; this astragal is three and five-tenths parts in height, of which two and five-tenths are for the bead and one for the fillet, the projection is two and five-tenths of which one and five-tenths is for the bead, and one for the congé.

71. The side face of the capital, called the "roll," unites the volutes of the two faces. It is forty-six parts in width and is divided in the center by a sunken band of six (or seven) parts in width which is ornamented with two bead mouldings of two parts each spaced one part apart. The height of this band below the abacus is fourteen, as shown in the section; the space included between it and the return or inner edge of the face of the volute is sixteen or sixteen and five-tenths. This part is bell-shaped, and its outline is obtained on the side of the capital as follows: Having prolonged the horizontal line marking the lowest point of the volutes, find on it two points, the one, two and five-tenths from the band at the center, the other five and five-tenths from the inner edge of the volute, and here erect two perpendiculars; on the first of which mark heights of four and five-tenths, and of eight and five-tenths, and on the second three and five-tenths, and nine and five-tenths. Four points *a*, *b*, *c* and *d* will be obtained by this means through which the curves may be readily drawn.

The section of the roll may be drawn thus: Draw the profile of the abacus and of the astragal. Then draw the exterior contour

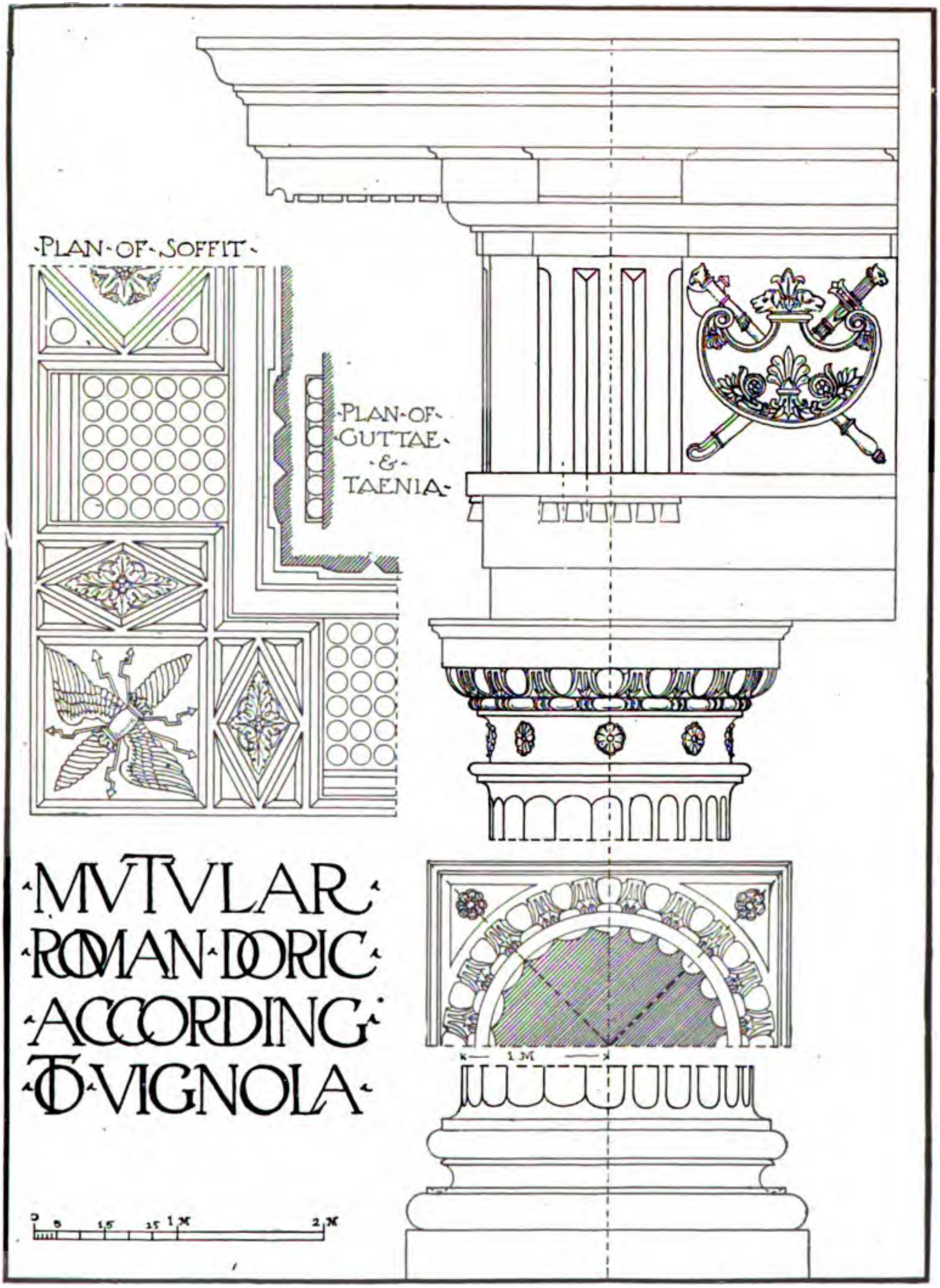

PLATE IX.

(A reproduction at small size of Portfolio Plate IX.)

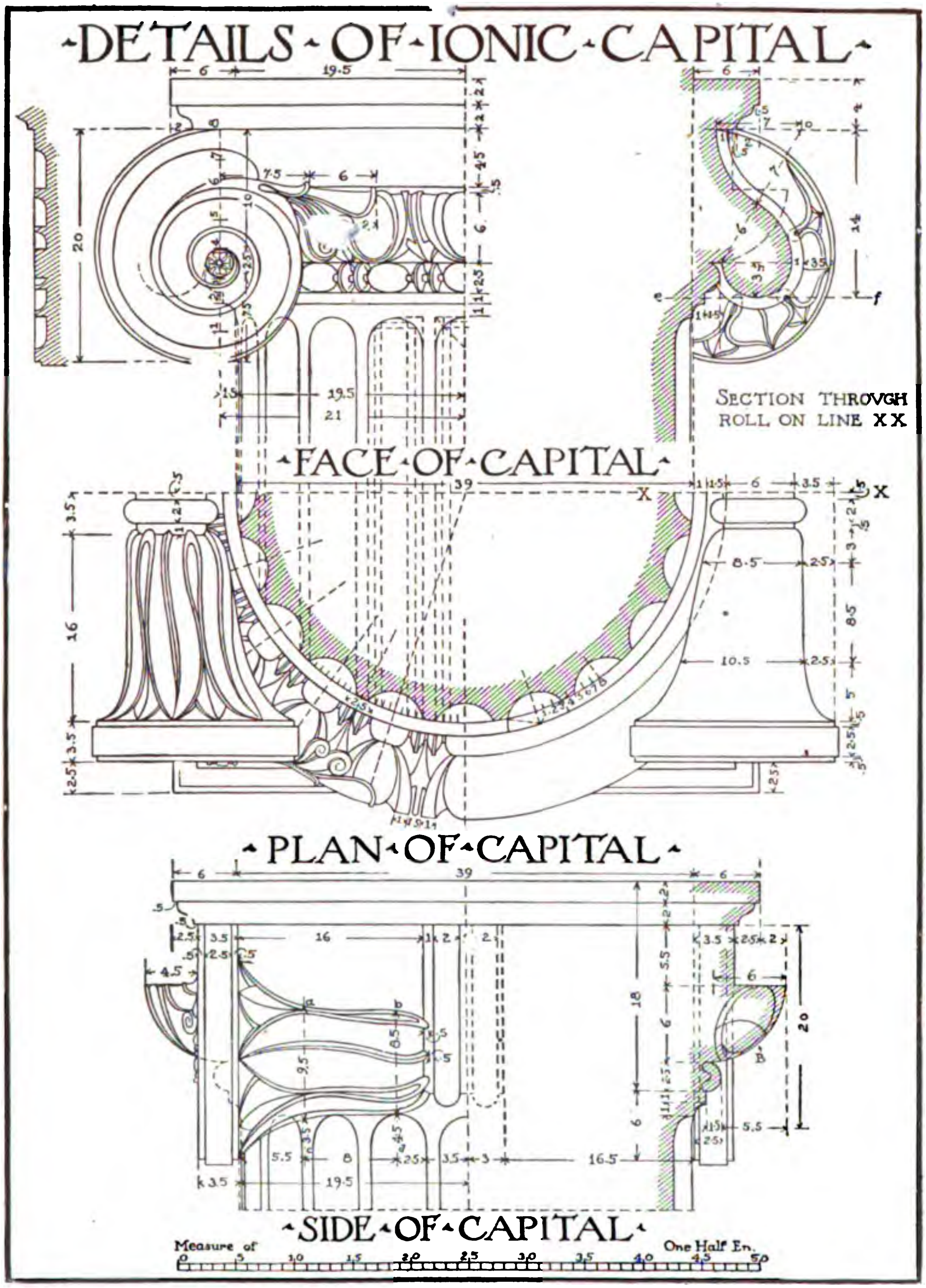

PLATE X.

(A reproduction at small size of Portfolio Plate X.)

of the volute as far as its intersection with the line of the shaft, by establishing the cathetus and the first three points of the squares 1, 2, 3, and 1″, 2″, 3″ in the eye. Draw a horizontal line *ef* marking the height of the center of the roll, fourteen parts below the abacus, and another horizontal three parts higher up. On the latter horizontal fix a point *h* six and five-tenths from the edge of the volute; from this point, with a radius of three, a semi-circumference may be drawn whose intersection with the horizontal *k* gives the center of the second arc of the section, which may be drawn with a radius of six. Then continue the lower line of the abacus and mark a point *o* three and five-tenths beyond its projection; this is the center of a third arc of the circle which may be drawn with a radius of seven.

72. The principal figure of this plate (X) is the plan of the capital, which shows the horizontal form and the disposition of the rolls, as well as the combination of the circular mouldings with the square mass of the capital.

73. The Ionic capital is generally enriched with carved ornaments, the quarter-round is carved with eggs and darts, the bead of the astragal is carved with bead and reel ornaments and the roll is carved with leaves, more or less detailed, while a rosette is frequently carved in the circle forming the eye of the volute.

74. The channels of the Ionic column differ from those of the Doric in the fillets which separate them; they are shown in this plate to be twenty in number, and the width of the fillet is equal to one-third of the width of the channel, so that, after having divided the circumference of the shaft into twenty equal parts, each of these is divided into eight, two of these eight parts being given to the fillet and six to the channel.

The plan of each channel is drawn from a center placed at a distance of one part outside of the circumference of the shaft, as is shown in the plate. (Plate X.)

75. The number of flutings of the Ionic shaft is frequently twenty-four instead of twenty, as here shown. In the attempt to differentiate between the Ionic and Corinthian capitals it is often desirable to allot a smaller number of flutings to the Ionic shaft. When this order is used at a small scale, it is very proper that the channels should be few in number, so as not to complicate the carving. For use in wood, however, twenty-four channels, with their centers placed on the line of the column circumference, are preferable, as they are sharper, more effective and better accord with the accepted number of seven flutings for the pilaster shaft.

The flutings as shown in plan on Plate X are very shallow and do not "tell" as much as should be expected of this method of ornamenting the column. It is therefore suggested that in actual practice the method and number of flutings shown on the plan of the Corinthian shaft, Plate XIX, be also employed on the Ionic.

76. The cornice of the Ionic order (Plate XI) is less complicated than that of the Doric, having, with the exception of the dentils, none but horizontal divisions. The cornice is forty parts in height and its projection is equal to its height.

Certain of the mouldings are carved with the leaf and tongue, the egg and dart, and the bead and reel, the perpendicular divisions of which correspond to the axes of the dentils, which in turn correspond to the axes of the columns. The frieze is thirty parts in height and undecorated; the architrave is the same height as the frieze, and is composed of three bands or fascias and a crowning moulding. The band which rests on the capital is six in height and its face is plumb with the upper diameter of the column and with the frieze; the second band is seven parts in height and projects one part beyond the lower; between the second and third bands occurs a cyma-reversa two parts high; this third band has a projection of one and five-tenths beyond the second. The assemblage of mouldings crowning the architrave is composed of a bead moulding of one and five-tenths parts, and a cyma-reversa of three, crowned by a listel of two and five-tenths. The projection of these mouldings beyond the third band is three and five-tenths, so that the extreme projection of the architrave is six.

77. The base of the Ionic order (Plate XII) is twenty-three and five-tenths parts in height; it is composed of a plinth of eight, a first torus of six, a fillet of one and five-tenths, a scotia of three, a second fillet of one, and a second torus of four. The projection of the base, including the congé of the shaft, is eight, of which two is the projection of the congé. This is shown on the enlarged section of the pedestal and column base at the left.

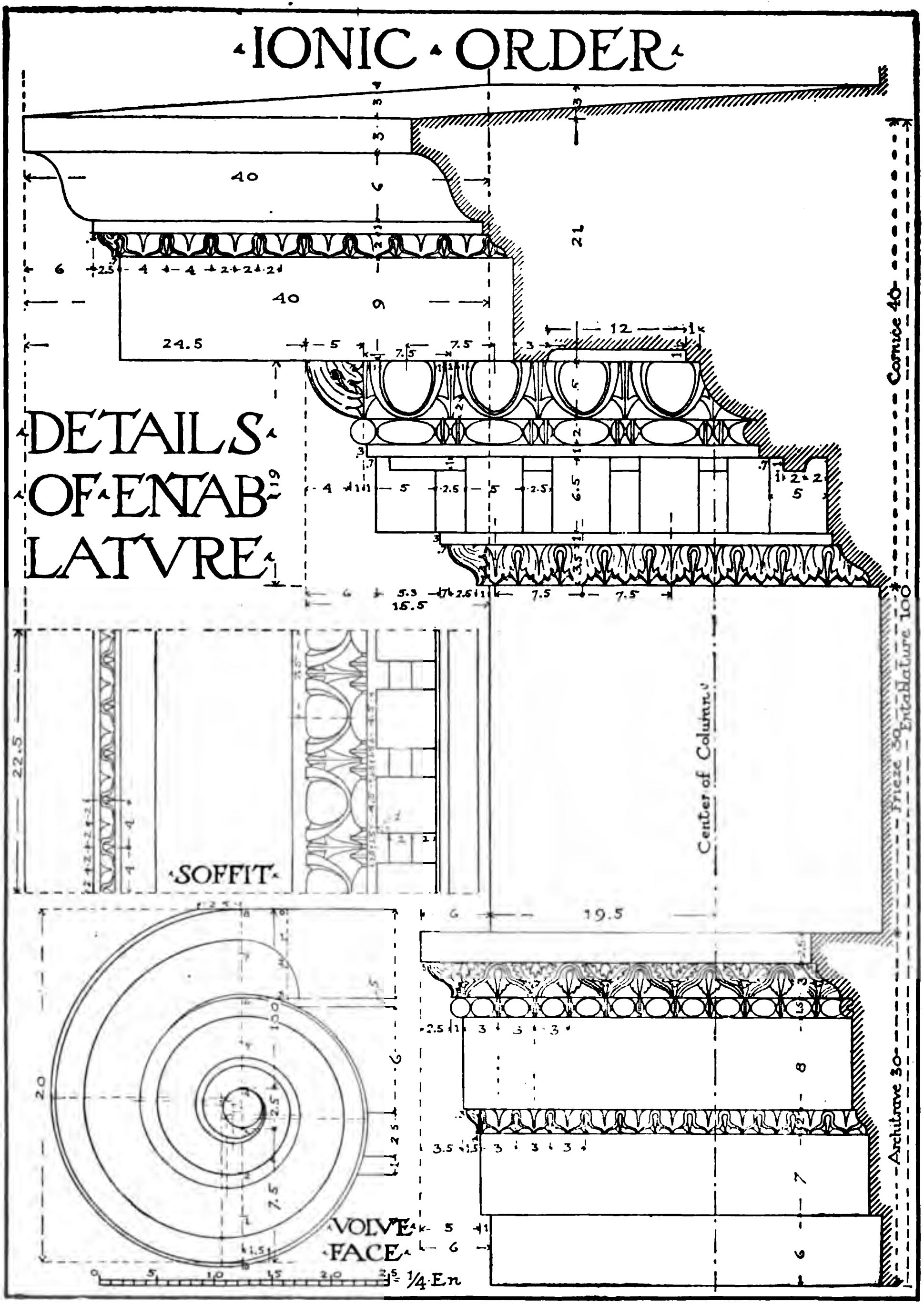

PLATE XI.
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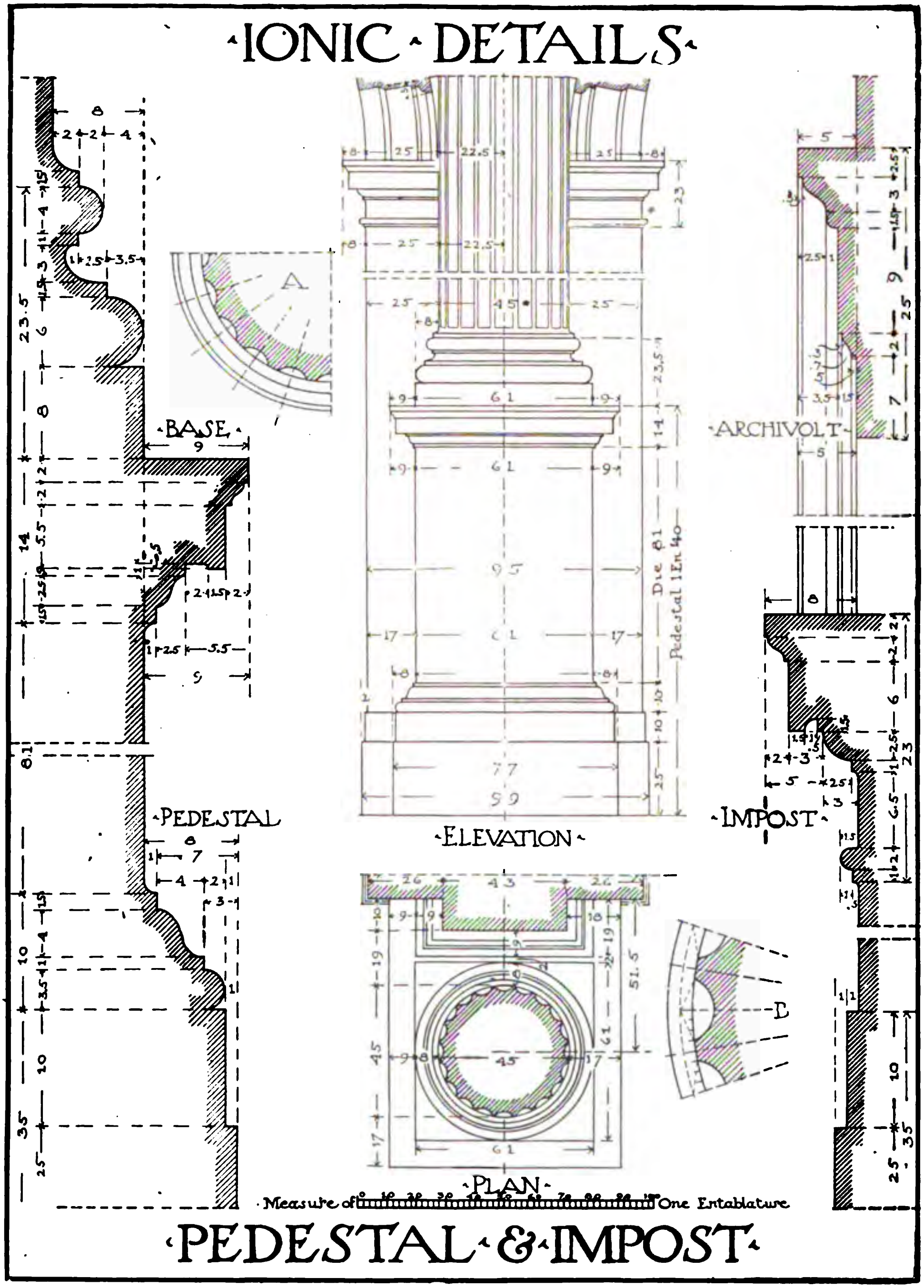


PLATE XII.

(A reproduction at small size of Portfolio Plate XII.)

78. The cymatium or cap of the pedestal is fourteen in height, divided as follows: a fillet, one and five-tenths, cyma-recta, two and five-tenths, surmounted by a small fillet of five-tenths, a corona of five and five-tenths, a cyma-reversa of two, and a listel of two. The projection of the cap from the plinth of the column base and the die of the pedestal is nine, of which two parts are for the cyma-reversa and listel, and three and five-tenths for the corona in which is cut a small drip. The base of the pedestal is forty-five in height divided thus: first plinth, twenty-five; second plinth, ten; torus, three and five-tenths; fillet, one; cyma-reversa, four; upper fillet, one and five-tenths. The projection of the base is eight, of which one is for the congé, four for the cyma-reversa, two for the torus, and one for the first plinth.

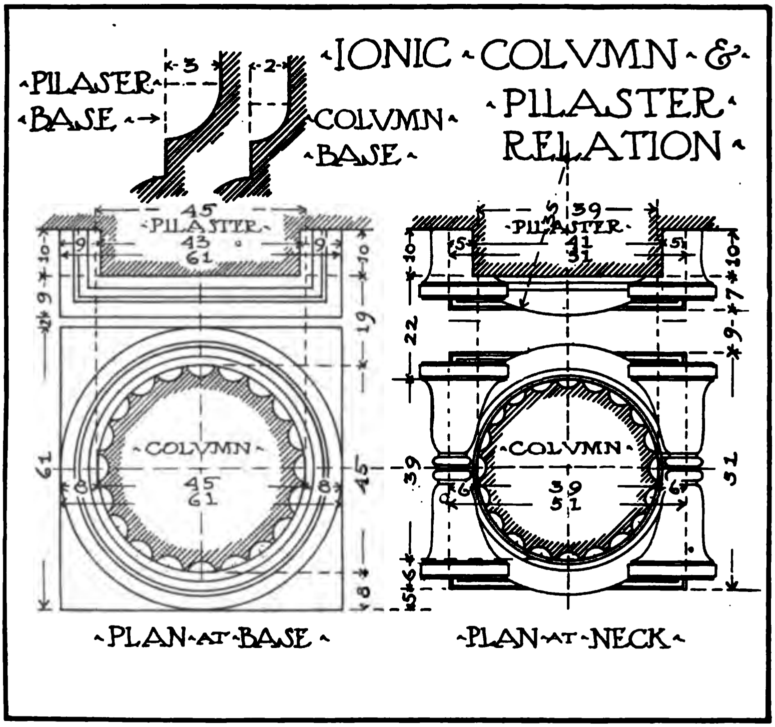


Fig. 12.

79. The impost is twenty-three parts high and is sub-divided as follows: astragal three; frieze six and five-tenths; fillet one;

quarter round, two and five-tenths; corona, six; cyma-reversa, two; listel, two. The projection of the impost is eight; two for the cyma and listel, three for the corona, and three for the quarter-round and fillet. The archivolt is twenty-five in width composed of a first band of seven, a cyma of two, a second band of nine, a bead of one and five-tenths, a cyma of three, and a listel of two and five-tenths. The projection of the archivolt is five, of which one and five-tenths is for the projection of the second band beyond the first, one for the bead, and two and five-tenths for the cyma and its fillet.

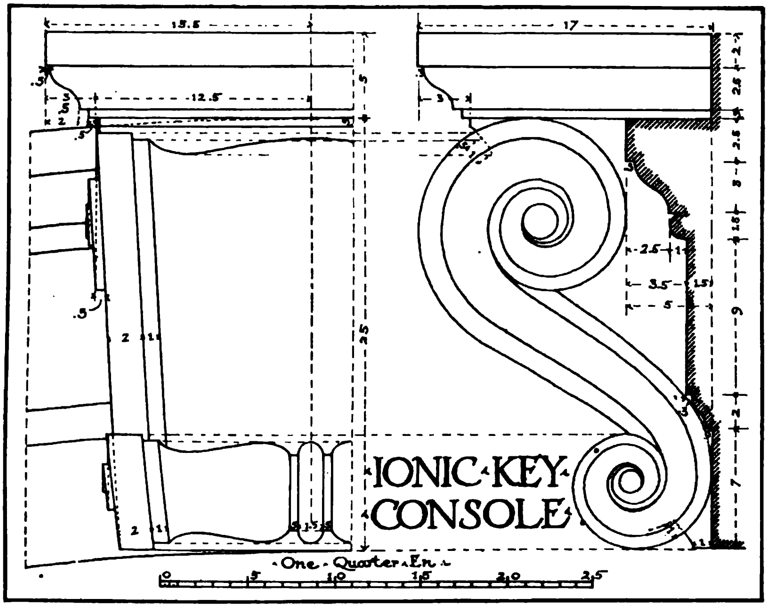


Fig. 13.

80. The relation of Ionic column taper to pilaster taper (Fig. 12) is as follows: The lower diameter of the Ionic column is forty-five, and its upper diameter thirty-nine, the difference is six, which, divided into three parts, as in the Doric order, gives for the lower width of the pilaster forty-three, and for the upper width forty-one. The projections of the bases differ only in the congé of the shaft which measures three for the pilaster and two for the column.

The disposition of the capital is the same for the pilaster as for the column so far as the volutes are concerned, the catheti being

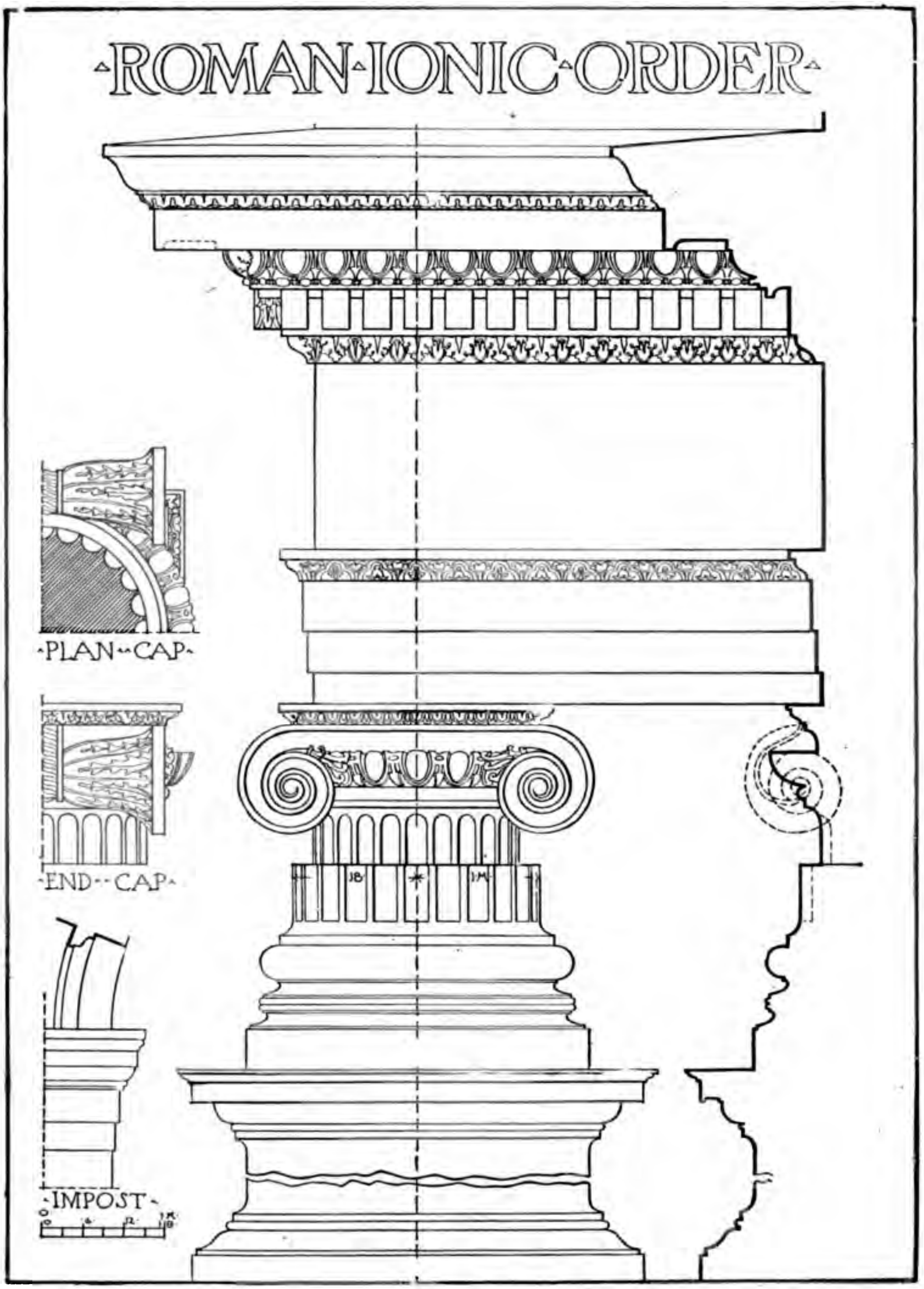


PLATE XIII.
(A reproduction at small size of Portfolio Plate XIII.)

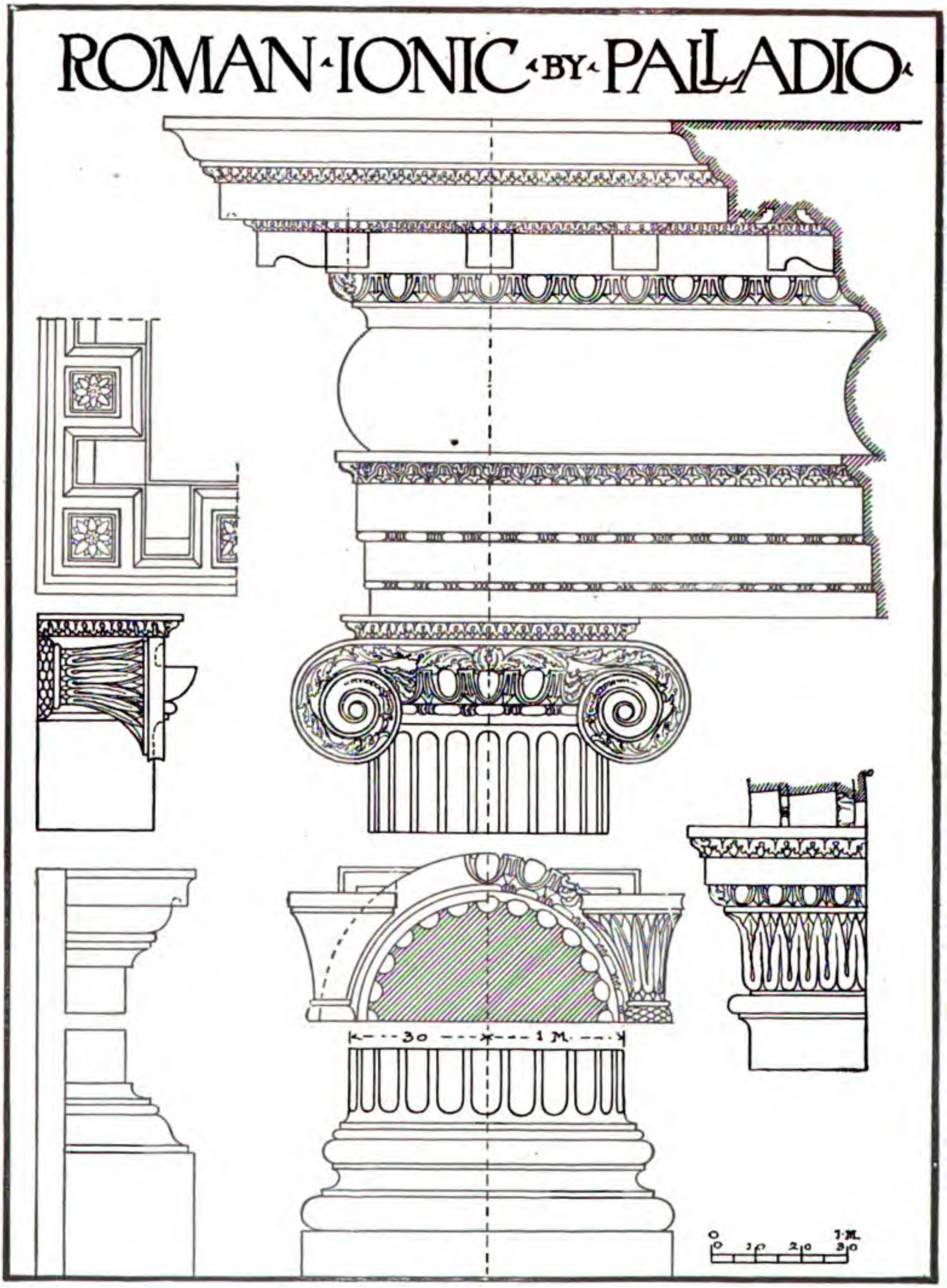


PLATE XIV.
(A reproduction at small size of Portfolio Plate XIV.)

the same distance (forty-two parts) from each other. It may be noticed only in the plan of the capital of the pilaster, that the outer edge of the quarter-round forms an arc of a circle drawn with a radius of thirty-five,while the astragal is rectangular in plan like the face of the pilaster, and, running between the volutes, connects them with one another.

81. In Fig. 13 will be found a drawing of the Ionic console. Sometimes one of these consoles is placed at the crown of an arch intersecting the archivolt. The sides of such a console radiate from the center of the arch; the stone on which the console is carved is called the "key" of the arch or the "keystone."

THE CORINTHIAN ORDER.

82 The Corinthian is an elaborately formal and dignified Order, and all the details which enter into its composition will bear analyzing with the greatest possible care.

83. The Corinthian capital (Plate XVII) is in form similar to a cylindrical vase covered by an abacus with hollowed sides and with corners cut at an angle of forty-five degrees, in plan with the sides of the square containing the abacus. Against this vase or "bell" are placed two rows of leaves whose heads are curved. The first row, which is applied directly above the astragal of the shaft, is composed of eight leaves; these are called the small leaves. From the intervals between these small leaves arise the stems of the second row of leaves which are larger. Between these large leaves and just over the centers of the small ones, eight stems arise, from which develop eight other leaves which, divided into two parts, recurve above the large leaves at the corners of the abacus and at the center of each of its faces. These leaves, which are very much distorted, are called caulicoli. From these caulicoli arise sixteen volutes of which eight large ones unroll in pairs, back to back, under the corners of the abacus, and eight small ones, also in pairs, extend towards the centers of the four sides of the abacus. Among the small volutes next to the bell is placed an ornament which is called the floweret, and above this, against the mouldings of the abacus, is a rosette.

84. The small leaf, Plate XVI, is placed on a vertical axis against the vase in such a manner that the base rests on the astragal and its face corresponds to the face of the shaft, so that, the leaves being one part thick at the bottom, the vase of the capital must be two parts smaller than the column at the neck.

The sweep of the leaf has a projection of six from the base and forms a delicately curved profile the shape of which may easily be determined from the plate. The squares represent a unit of two parts in all cases.

The developed width of the leaf is equal to its height, thirteen parts. It is represented in front elevation, half developed to its full height, and half in its recurved position as it is placed on the capital. The developed half shows the under part of the curved top; it may be seen that a perpendicular axis divides the leaf into two perfectly symmetrical halves, each halt being divided into four divisions which themselves are sub-divided—the topmost and lowest ones into four pointed lobes, the two others into five.

Notice that in order to present the ordinary profile above the astragal, the leaf preserves its entire mass in the lower part for a small distance above the base.

85. The large leaf, (Plate XV) which grows from above the astragal, in the small space between two of the smaller leaves, (see Plate XVII) projects nine parts beyond the upper diameter of the shaft. Its details are in almost every particular similar to those of the small leaf.

86. The stems of the caulicoli (Plate XVI) are channeled batons or staves each crowned by a calix from which the distorted leaf or caulicolus springs (Plates XV and XVI.)

87. It may be noticed that in the direct elevation (Plate XVI) the enrollments of the volute are arranged in the form of a cork-screw, and the section shows the manner in which their faces are hollowed out. The floweret (Plate XV) is seen only in direct elevation in the general plate, being attached to the vase on the axis of each space between the smaller volutes. It is shown separately on this plate, with a horizontal section.

88. This same plate shows the detail of a rosette having six divisions, in the center of which is found a slug whose tail is turned upward.

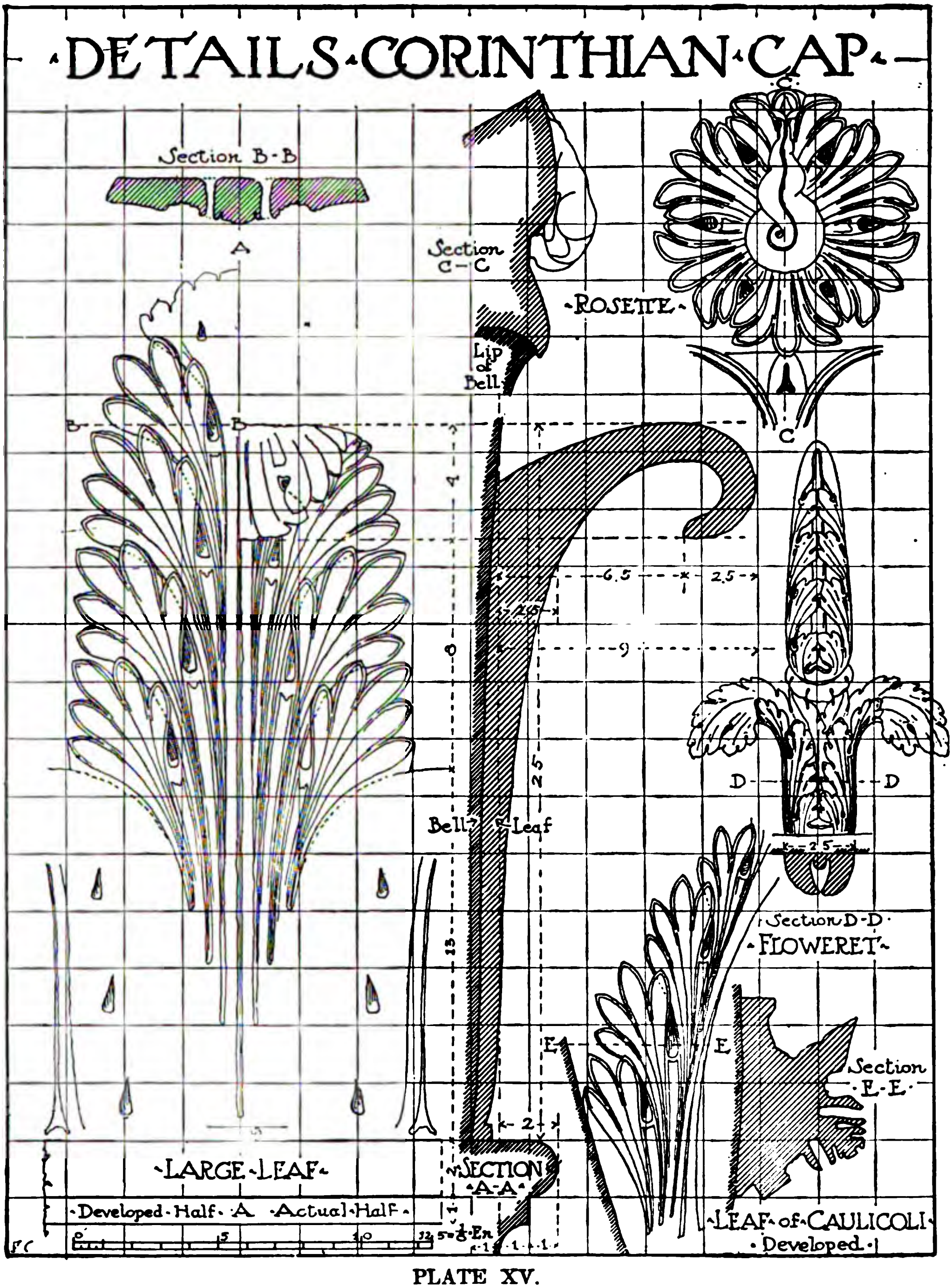


PLATE XV.
(A reproduction at small size of Portfolio Plate XV.)

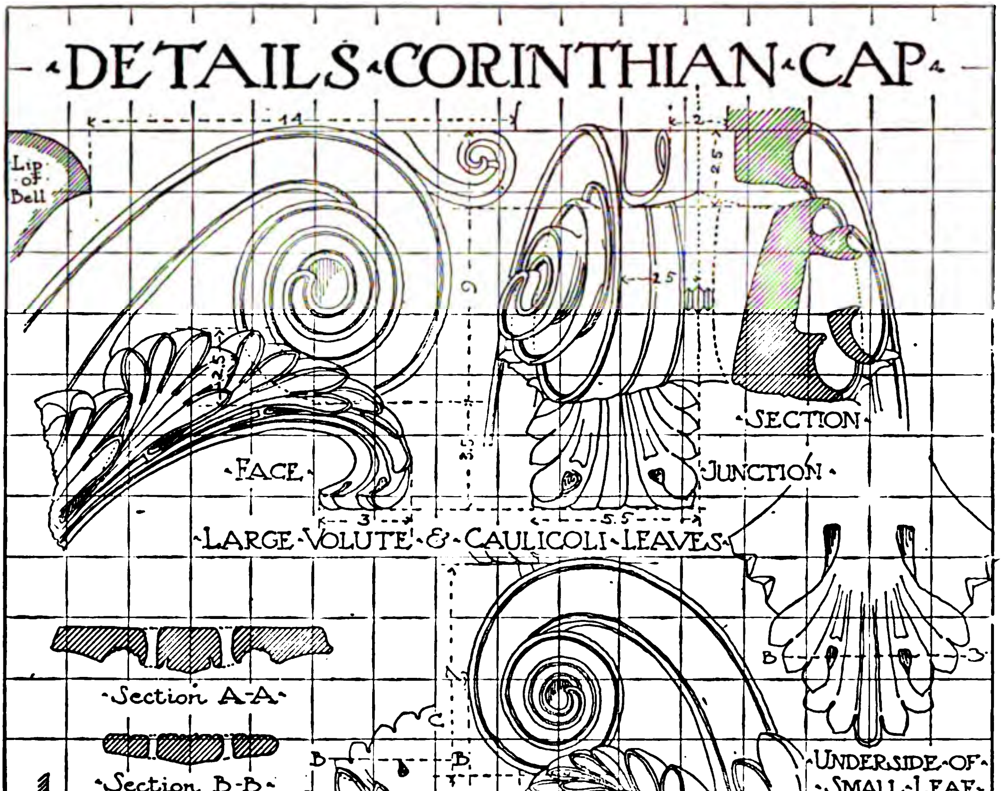


PLATE XVI.

(A reproduction at small size of Portfolio Plate XVI.)

89. The upper part of the Corinthian capital is a drum in the form of a bell whose upper edge is decorated with a curved moulding called the lip. The bell is forty parts in height; its lower diameter (directly above the astragal of the column) is thirty-four, —two parts less than the neck of the column,—and its upper diameter at the edge of the lip is forty-four. This difference of diameter forms a section or outline starting at the astragal and extending in a delicate curve up to the edge of the lip.

It is against this vase or bell that all the ornaments that have been detailed are attached. In order to draw each one in its own place in the general elevation—after having made the section, or profile, of the bell, with the astragal of the shaft—mark on a vertical line the height of the small leaf, thirteen parts; above this the height of the large leaf, twelve; then the distance above the large leaves up to the volute, six; next mark the height of the turn-over of the small and the large leaves, four; and the turnover of the caulicoli, three and five-tenths. Through all these different points draw horizontal lines across the width of the bell. All the projections are figured from verticals erected from the face of the column above the astragal. The small leaf projects six, the large one nine, the leaf of the caulicolus fifteen and five-tenths, and the volute seventeen.

90. In order to draw the elevation of the Corinthian capital it is necessary to consider first its outline as a section, and to lay out carefully, in plan, the arrangement of its leaf ornaments, as shown in Plate XVII. By means of this section and plan, the elevation may be exactly determined, after the individual parts, with their arrangement, are thoroughly understood.

91. The capital of the pilaster is composed of the same elements as that of the column; but as the plan of the pilaster is square the forms are slightly different; thus the vase, which is square at its base above the astragal, has convex faces; each face of the vase has two small leaves square in plan, and centering on perpendiculars at a distance of nine from the center line. Larger leaves are placed in the center of each face and at each angle. The abacus and other details are exactly similar to those of the capital of the column.

92. The Corinthian architrave (Plate XVIII) is thirty parts in height and divided into three bands; the first, five and five-tenths; second, six and five-tenths; and the third, seven and five-tenths. Between the first and the second there is a bead of one; between the second and the third, a cyma of two; above the third face there is a bead of one and five-tenths; cyma-reversa, three and five-tenths; and a fillet, two and five-tenths. The total projection of the architrave from the frieze is five and five-tenths.

93. The frieze has the same height as the architrave, and is terminated against the cornice by an astragal of one and five-tenths, of which five-tenths is for the fillet and one for the bead.

94. The Corinthian cornice has a total height of forty parts and its projection is equal to its height. It is divided thus: first, a cyma of three; second, a flat band of six and five-tenths, against which is placed a row of dentils five and five-tenths deep; third, an astragal one and five-tenths; fourth, a quarter-round three and five-tenths; fifth, a flat band of seven, against which are placed modillions six and five-tenths parts deep; sixth, a cyma of one and five-tenths which is mitred around the modillions and which crowns them; seventh, a corona of seven; eighth, a cyma of one and five-tenths; ninth, a fillet of one; tenth, a cyma-recta of five, and a fillet of two and five-tenths.

The total projection of forty is divided as follows: four parts for the cyma, four for the dentils, five for the astragal, the quarter-round, and the flat band of the modillions; eighteen for the modillions up to the lower angle of the cyma; one for the cyma reversa; one for the corona; two for the upper cyma and its listel; and five for the cyma-recta.

95. The cornice of the Corinthian order is distinguished by the consoles which support the corona and which are called modillions. The modillion is composed of two volutes or spirals similar to the keystone which we have already analyzed in Fig. 16, but while in the keystone the large spiral is found at the highest part, in the console it is at the back and attached to the face of the cornice.

The lower side of the modillion is covered by an ornamented leaf, whose head curves back against the smaller volute. The general proportions and curves of this leaf are indicated in Plate

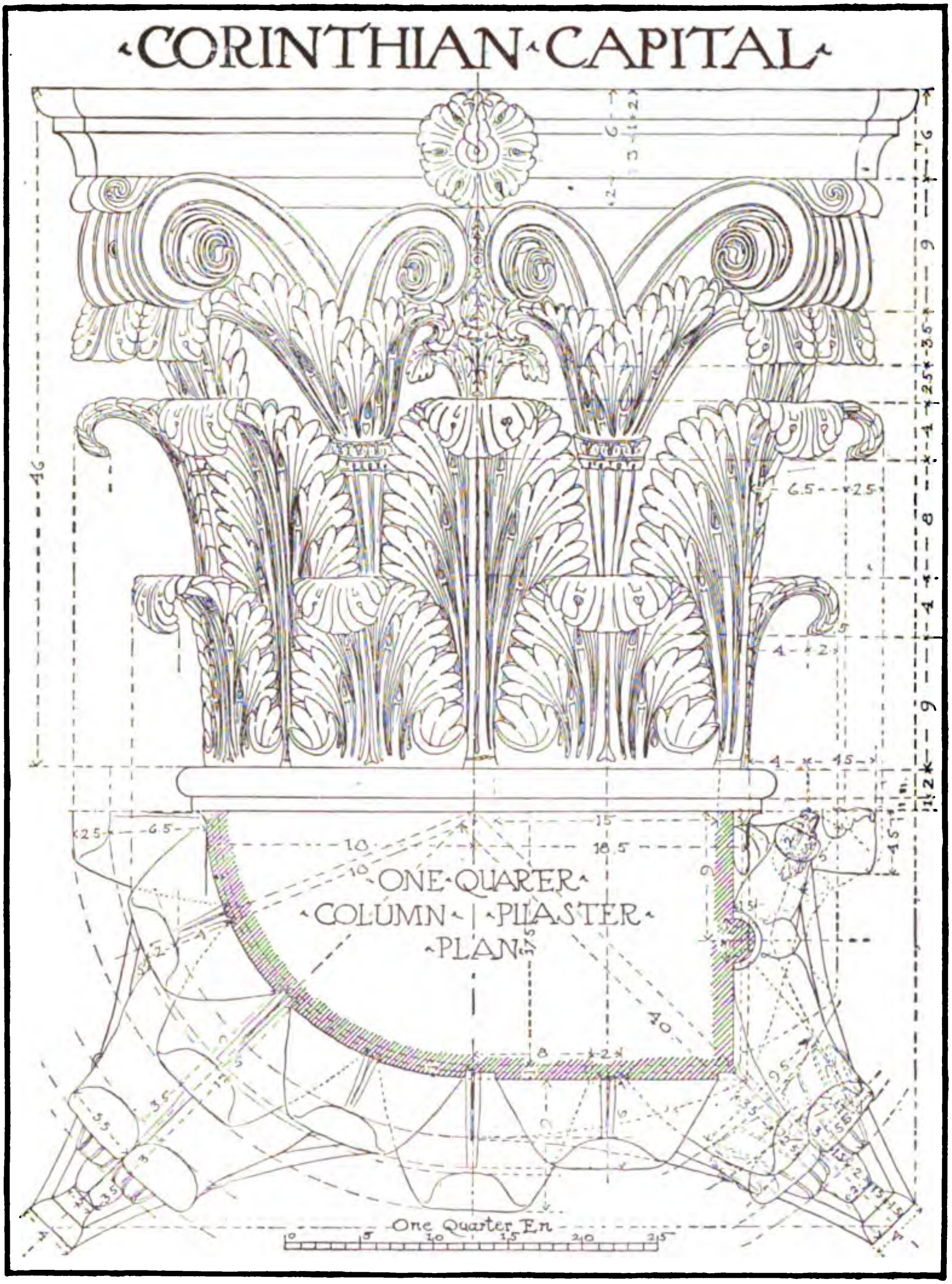


PLATE XVII.
(A reproduction at small size of Portfolio Plate XVII.)

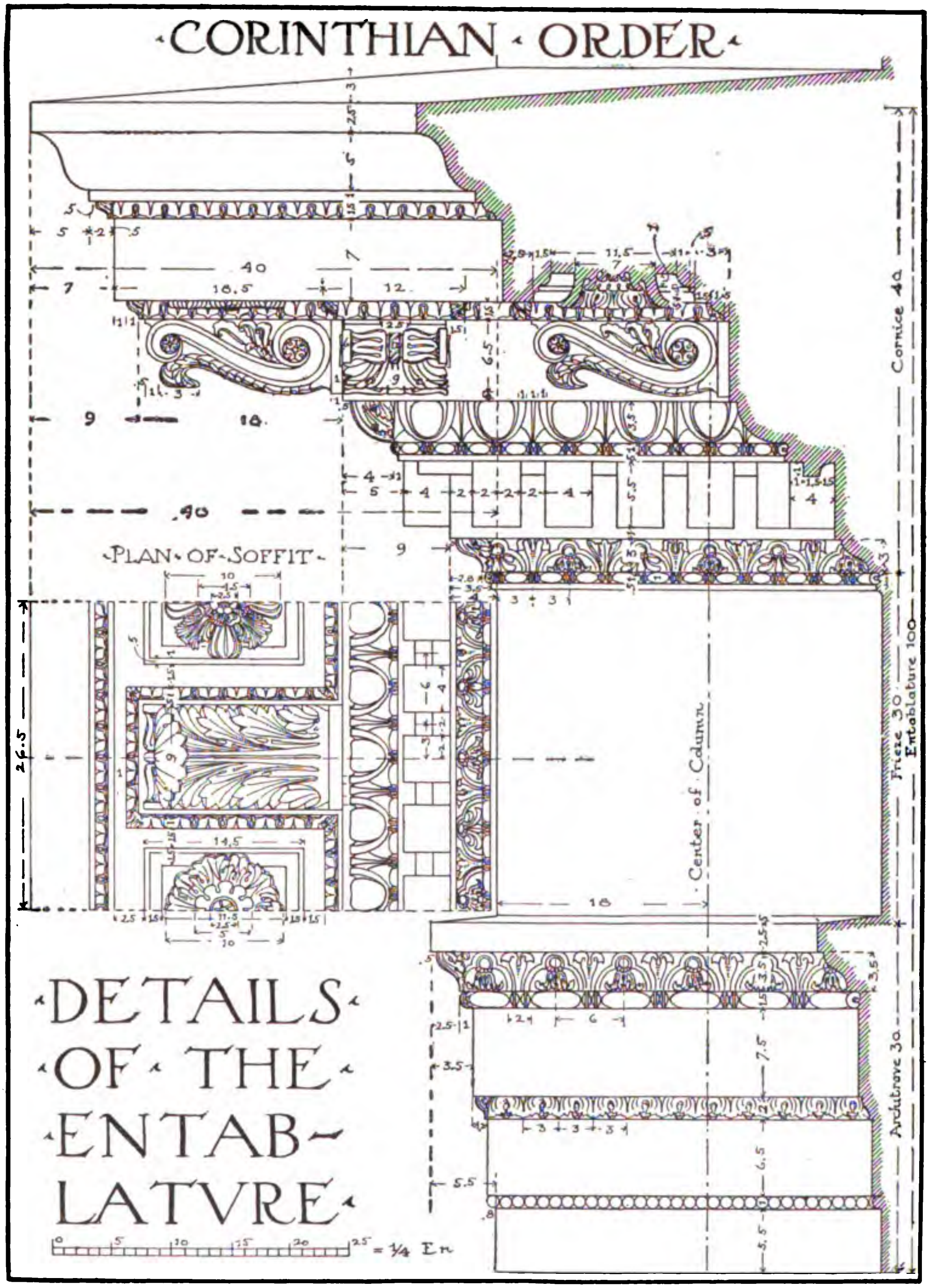


PLATE XVIII.
(A reproduction at small size of Portfolio Plate XVIII.)

XVIII. In practice, the console is drawn free-hand after laying out the general proportions.

The modillions are nine parts in width and are spaced seventeen and five-tenths apart or twenty-six and five-tenths from center to center; the dentils are four parts wide and are two apart. Against the cyma-recta very frequently is placed a row of masks in the form of lions' heads to serve as water spouts. These masks occur over the center of the modillions.

The soffit of the corona is ornamented between the modillions, with panels containing rosettes. (Fig. 14.)

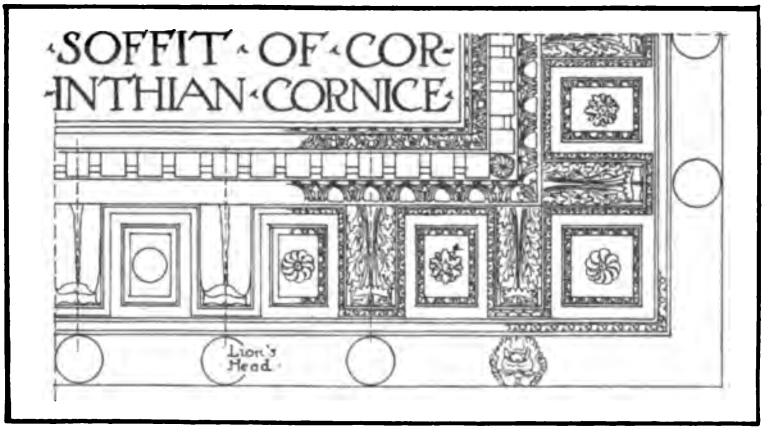


Fig. 14.

96. The base of the Corinthian Order (Plate XIX) is composed of a plinth, two torus mouldings, and two scotias separated by a double bead. Its total height is twenty-three, of which seven and five-tenths is for the plinth; five and five-tenths for the first torus; one for the fillet; one and five-tenths for the first scotia; two for the beads and their annulets; one and five-tenths for the second scotia; five-tenths for its listel; and three and five-tenths for the second torus.

The total projection of the base is eight; in this is included the congé of the column whose projection is one and five-tenths.

97. The cap of the pedestal is twenty parts in height divided among an astragal of two, a small frieze of five and five-tenths, second astragal of two, a cyma-recta of two and five-tenths, corona of five, a cyma-reversa of one and seven-tenths, and a fillet of one and three-tenths. The total projection of the cap from the die of the pedestal is eight.

The base of the pedestal is forty parts in height; it is composed of a first plinth of twenty-four, a second plinth of six, a torus of three and five-tenths, a reversed cyma-recta of three and five-tenths, with a fillet of one, a bead one and five-tenths, with a fillet of five-tenths. The total projection is seven and five-tenths, of which one is for the first plinth.

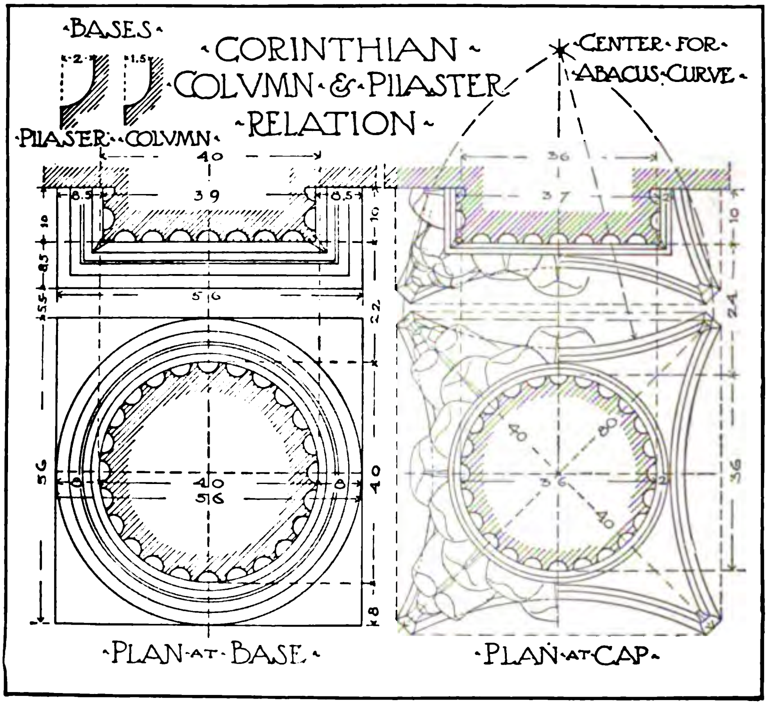


Fig. 15.

98. The impost is twenty parts in height and is composed of an astragal of two; frieze, five and five-tenths; fillet, five-tenths; bead, one; quarter-round, two and five-tenths; corona, five; cyma-reversa, two; and listel, one and five-tenths.

The total projection of the impost is seven, but for the arches between which a column with a pedestal is used, there is a greater projection of the corona of the impost. In this case the impost projection is eight.

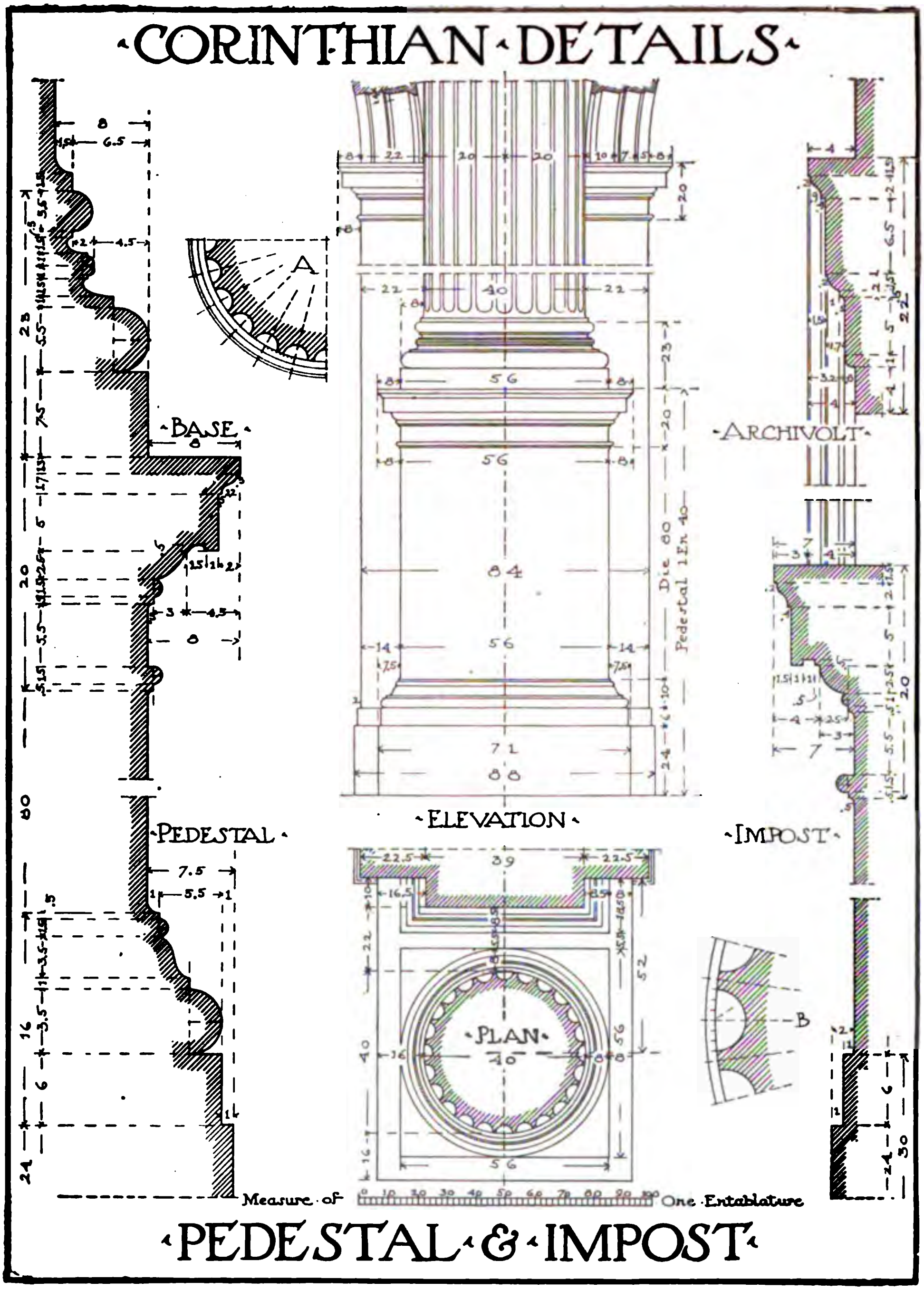


PLATE XIX.

(A reproduction at small size of Portfolio Plate XIX.)

99. The archivolt is composed of three fascias, a bead and quarter-round with a fillet, and a cyma-reversa with fillet. Its width is twenty-two parts; the first fascia four; bead one; second fascia five; fillet five-tenths; quarter-round one and five-tenths; third fascia six and five-tenths; cyma two; and fillet one and five-tenths. The total projection is four.

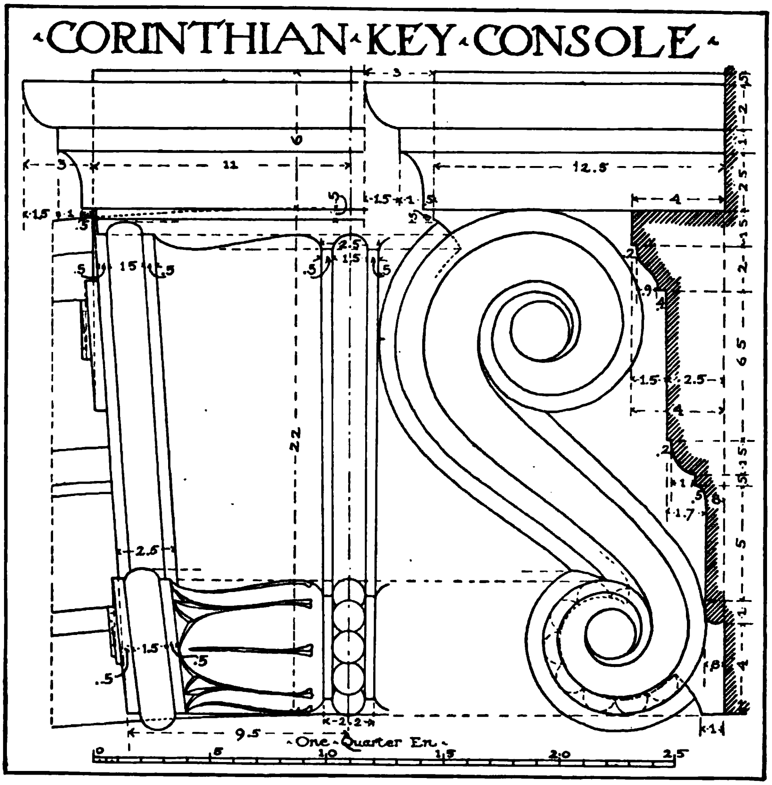


Fig. 16.

100. The channels of the Corinthian column are twenty-four in number. The width of the fillet which separates them is one-third of the channel width. The width of a pier of the arcade is equal to the width of a column plus two archivolts which is eighty-four parts.

101. The Corinthian pilaster and column relation is shown in Fig. 15: the pilaster width at the base is thirty-nine; at the height of the capital it is thirty-seven. The width of the pilaster differs from the diameter of the column, being one part less at the base and one more at the height of the capital. The base of the pilaster projects eight and five-tenths so that the total width may be equal to that at the base of the column. The width of the abacus of the pilaster capital is equal to that of the capital of the column.

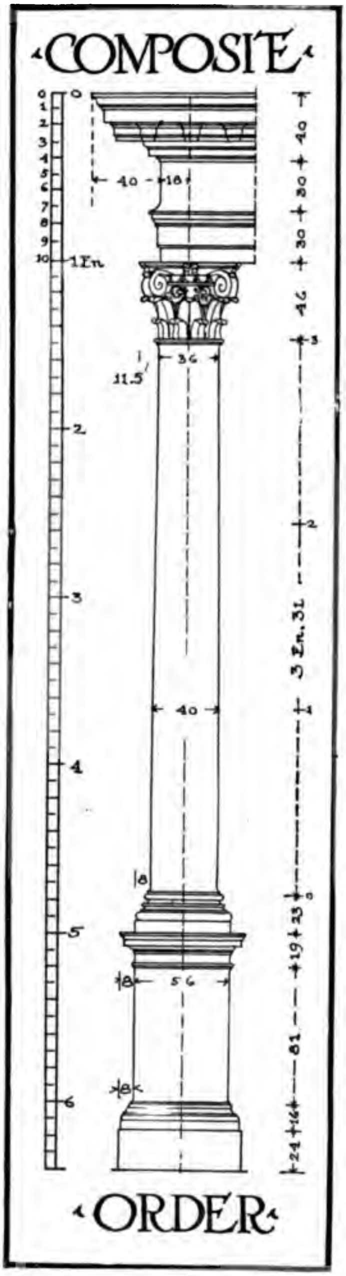


Fig. 17.

102. When the pilaster is channeled, there is formed at each angle a bead of one part and the remaining width is divided into twenty-nine equal spaces which in turn are divided into seven channels of three spaces, and eight fillets of one space each. The summits and the bases of the channels correspond to the starting point of the congés.

This rule for fluting of columns and pilasters is also applicable to the Ionic Order.

103. The drawing of the keystone console of the Corinthian arch as shown in Fig. 16 is a little different from that of the Ionic Order, but is drawn in accordance with the same rules.

THE COMPOSITE ORDER.

104. The Composite capital (Fig. 17) is a mixture of elements of the Ionic and Corinthian capitals. Its forms and general proportions are like those of the Corinthian Order. There are two banks of leaves placed as in the Corinthian, but the upper part is

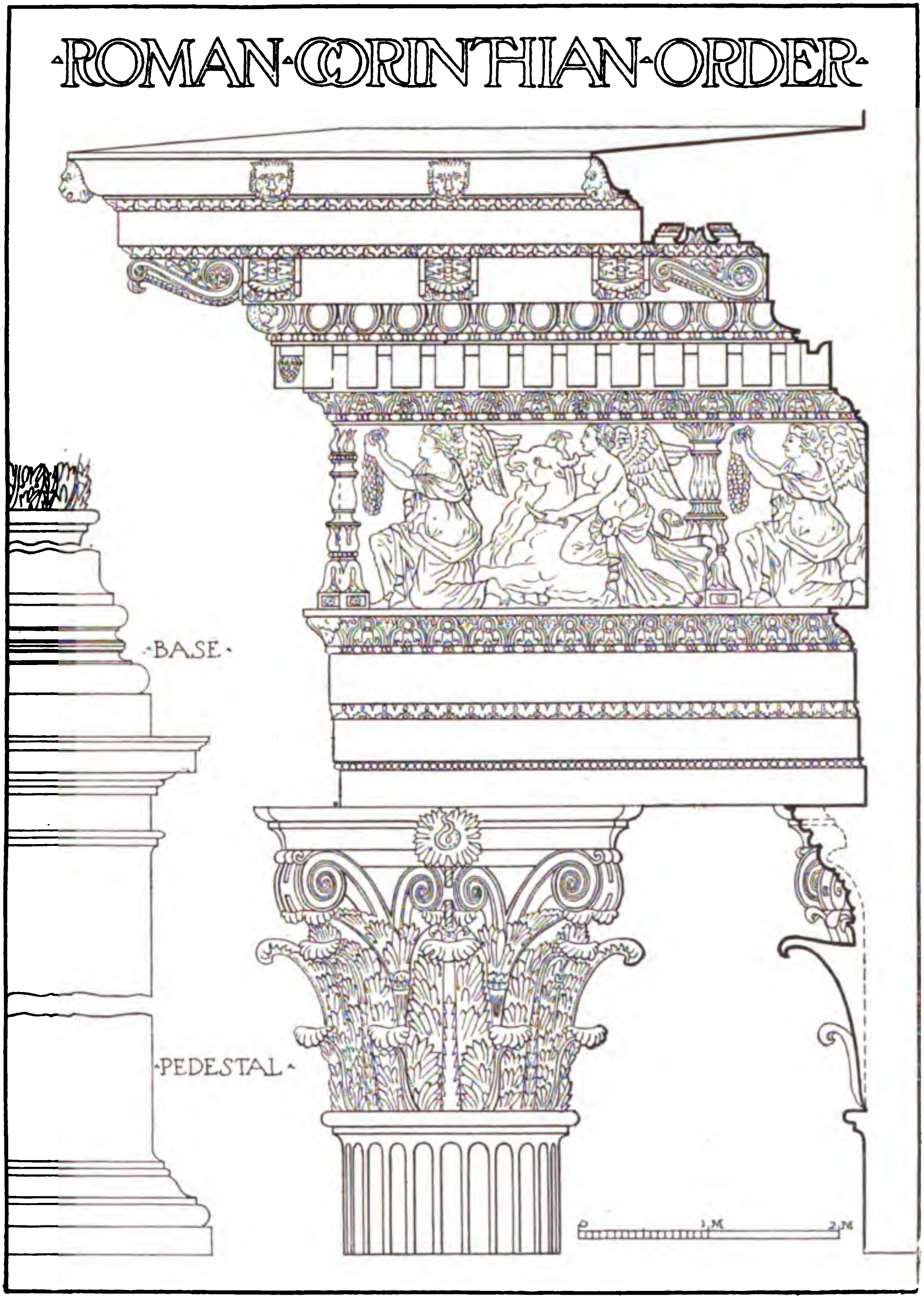


PLATE XX.
A reproduction at small size of Portfolio Plate XX.)

in the form of an Ionic capital whose volutes are placed on the angles.

105. The general proportions of the Composite entablature are the same as those of the Corinthian, but their details are appreciably different in the cornice, where the modillions are replaced by a sort of double mutule having two fascias.

106. We have now arrived at the close of the analysis of all the details which enter into the composition of the three Orders of Classical Architecture, and it will be advisable to take up briefly the consideration of their use in relation to each other, especially in regard to the principles governing their intercolumniation and superposition.

INTERCOLUMNIATION.

107. Intercolumniation is the spacing of columns *in the clear*, especially of columns arranged in the form of a colonnade. When a figured dimension refers to the spacing it is invariably one diameter less than the distance from center to center of columns.

108. Superposition has reference to the use of the orders in two or more stories, when certain general principles always apply, as will be shown.

109. A colonnade is a row of columns spaced regularly and connected by an entablature. The space which separates these columns is called the intercolumniation. When the colonnade is composed of two or more rows of columns and the space which they enclose is covered and serves as a covered porch or entrance to a building, this porch is called a portico, and it is often crowned with a gable or pediment above the columns. Usually one side of a portico is closed by a wall, and sometimes three sides are so closed; in such a case the columns at the angles are replaced by pilasters to which the side walls are attached. Pilasters which are employed in this manner are called antae, and a portico of this kind is a portico "in antis." The term "antae" is more generally employed in Greek work and the term "pilaster" is used in Roman architecture.

110. When the portico is employed as a porch in front of an edifice, the columns are generally of an even number, and the spaces of uneven number, in order to have a space in the center opposite the door-way of the building. Even when an entrance is not placed behind the center of a colonnade it is considered in better taste to place the columns or arches so that a support does not come in the center of any such arrangement. When a pediment is placed over columns this rule is even more strictly followed. Occasionally, usage determines that the intercolumniations of a portico shall be unequal so that the central opening may be wider than the others, in order that the approach to the entrance to the building may be more ample.

111. The intercolumniation of the Roman Doric order is determined more or less by the fact that the columns are invariably placed directly under the triglyphs. It will be found difficult to space two columns under two adjacent triglyphs, because the bases and caps of the columns will overlap each other. Still, they may be so placed by enlarging the spaces between the triglyphs or reducing the projection of the cap and base, or both. It is not often that circumstances would justify such an alteration in the order to effect a close spacing of columns. When the columns are set under alternate triglyphs they are spaced about two and one-half diameters on centers. The intercolumniation is then one and one-half diameters, or as it is termed "monotriglyphic" or "pycnostyle," (Fig. 18). The width of the intercolumniations (spaces between columns) of a portico should seldom be less than one and one-half times the diameter of the column, and in old work it will rarely be found to exceed two and one-half diameters. In modern practice as in exceptional cases in

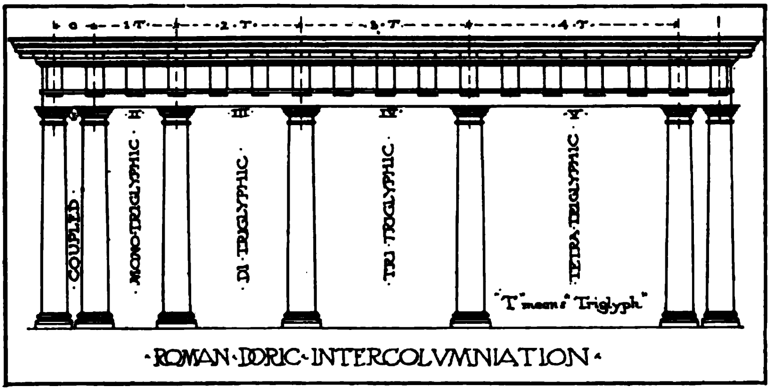


Fig. 18.

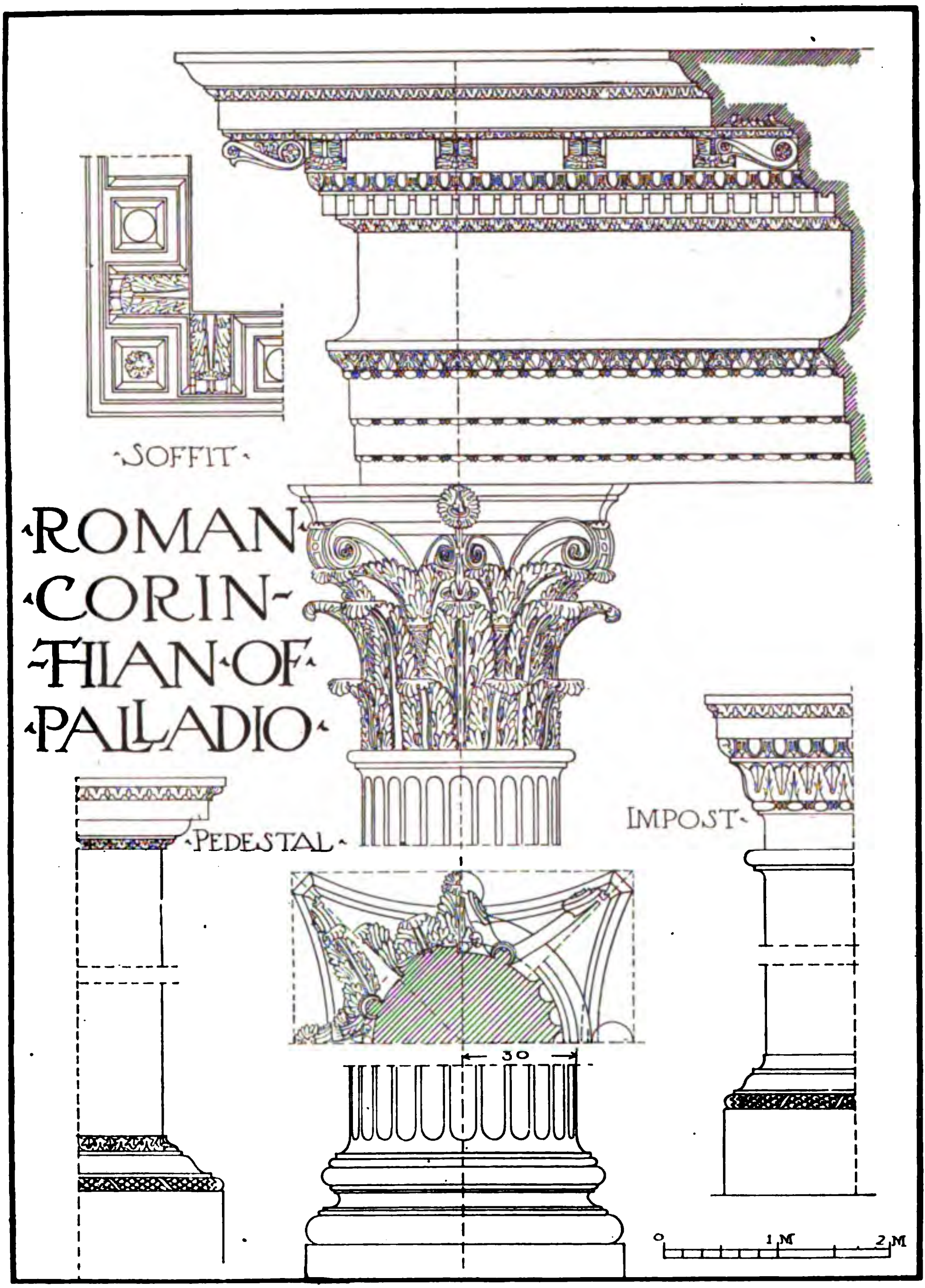


PLATE XXI.

(A reproduction at small size of Portfolio Plate XXI.)

ancient work, this spacing is, however, exceeded. When two triglyphs occur over the opening between the columns the intercolumniation is about two and three-fourths diameters, and is called "ditriglyphic." Too great an intercolumniation produces a bad effect in all the orders. However, when the order is executed in wood a much wider spacing is often employed.

112. In the spacing of columns other than in Doric Order there is no such special requirement as to the location of the column under any particular part of the entablature, although where modillions or brackets are used they should be so spaced as to come over the axes of the columns. Such modillions or brackets are, however, easily varied slightly in spacing or location, so that the system of intercolumniation in any other than the Doric Order is generally determined only by the diameter and height of the columns themselves. Columns are referred to as "coupled" when they are so placed that the bases or caps just avoid touching. This would space them about one-third to one-half their diameter apart, which is the least spacing that the outline of the column itself will allow. The various spacings of columns are generally termed coupled, pycnostyle, systyle, eustyle, diastyle, and arœostyle according as they are placed close together or are separated by 1, 1½, 2, 2¼, 3 or 4 diameters. (Fig. 19.) The spacing of the coupled

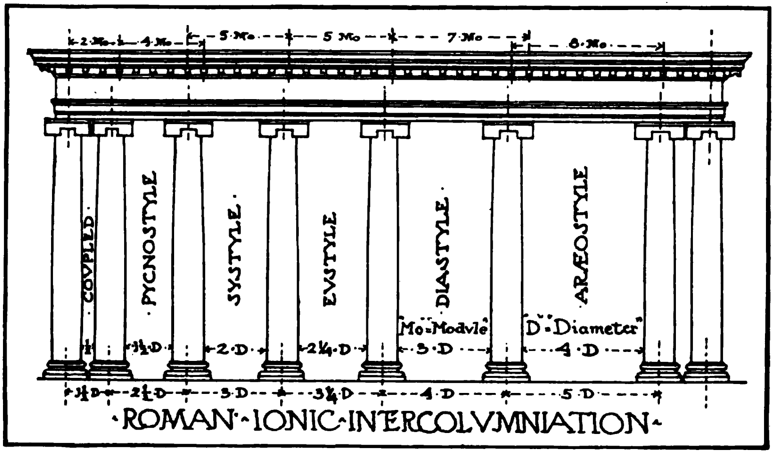


Fig. 19.

columns we have already explained. The pycnostyle intercolumniation varies from one and one-quarter to one and one-half diameters. The systyle intercolumniation has two diameters which in modern work would often seem too little. The eustyle has two and one-quarter diameters between the columns; or, as is sometimes preferred in modern practice, two and one-third diameters as in the Ionic and Corinthian orders. This corresponds more exactly to the customary spacing of dentils and modillions.

113. Closer intercolumniations are generally used on monumental work of large scale, while that of a more domestic character requires a wider spacing of columns for practical utilitarian purposes. During the Renaissance, the custom of placing columns in couples and taking each couple as a unit for working out the colonnade, was first adopted and has since, especially in France, been much employed. In modern practice the columns are placed less by rule than to satisfy the eye and the judgment of the designer. It must be remembered, however, that the axes of the columns must always be in accord with certain members of the entablature above, such as the triglyphs, dentils, or modillions, and also that, under a pediment, the columns themselves should be even in number.

114. A portico forming the front facade of an edifice, when there are not more than seven intercolumniations, may be crowned by a triangular gable or pediment which forms the roof of the porch.

115. A pediment is placed above the cornice of the entablature and is formed by two sloping cornices which are joined at the angles to the horizontal cornice. The crowning cyma-recta or cavetto follows the sloping cornice and is omitted from the horizontal cornice below the face of the pediment. The triangular face which is found between the three cornices corresponds in plane with the frieze of the entablature and is called the "tympanum" of the pediment.

The height of a pediment is determined as follows. In Fig. 20 let A be the point in which the axis of the pediment intersects the highest line of the horizontal cornice. With this point as a center and with a radius equal to one-half the width of the pediment, draw a semi-circle below the pediment as shown in the figure. This

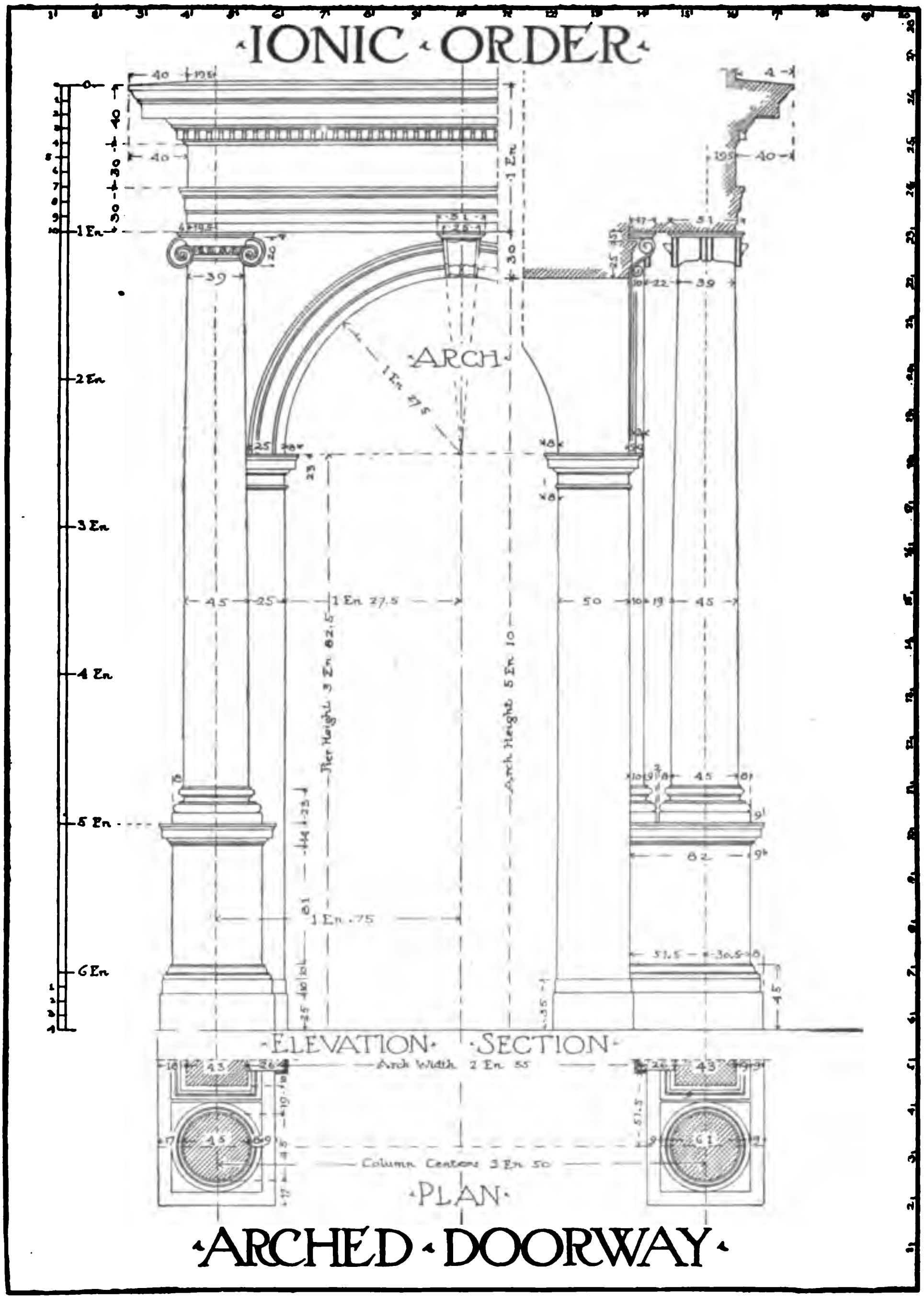


PLATE XXII.
(A reproduction at small size of Portfolio Plate XXII.)

semi-circle intersects the axis of the pediment at the point B. With B as a center and with a radius equal to the distance from B to C (the extreme outside point of the horizontal cornice) draw an arc above the cornice. The point D, in which this arc intersects the axis, will be the highest point or "peak" of the pediment. Draw the lines DC and DE and the outline of the pediment will be complete.

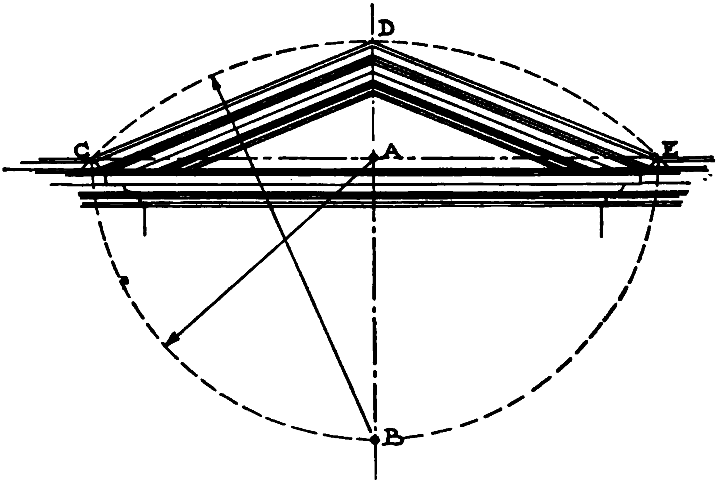


Fig. 20.

In plate XXXIII is represented a portico of the Ionic Order with three intercolumniations which forms the front of an edifice intended for a hall or temple. The plan is a parallelogram of which the front or portico occupies one of the smaller sides.

SUPERPOSITION OF THE ORDERS.

116. The principles governing superposition, or the use of orders one above the other, as we find them in many of the Roman and Renaissance buildings, is that the natural method is followed in placing a lighter and apparently more delicate order above one of greater strength. For instance, the Tuscan should never be other than the lowest order, and the Doric should be placed above this. As we have already seen, however, the Tuscan Order may better be omitted and the Doric Order may be placed in the lowest story with the Ionic and Corinthian above in the order named.

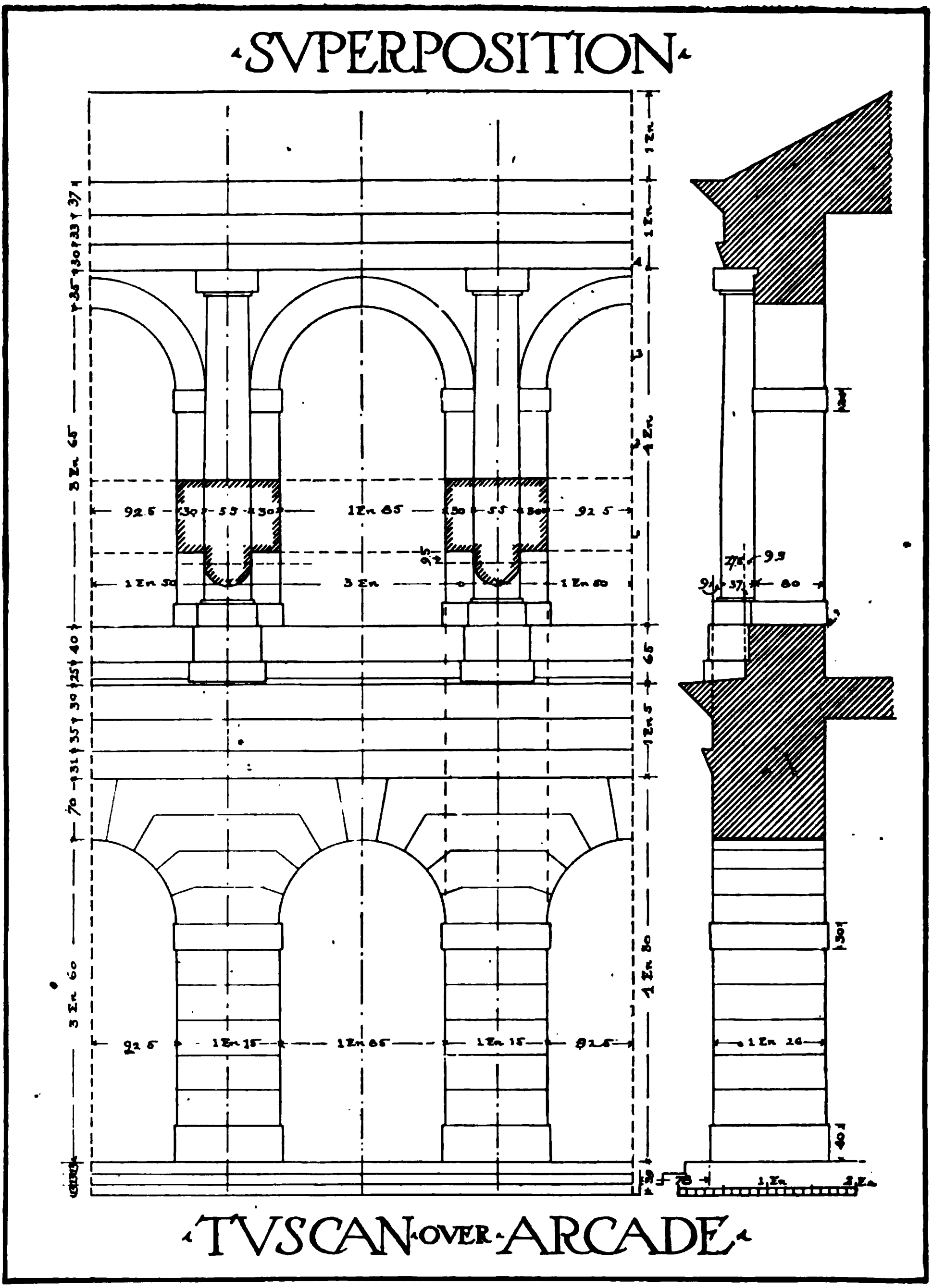
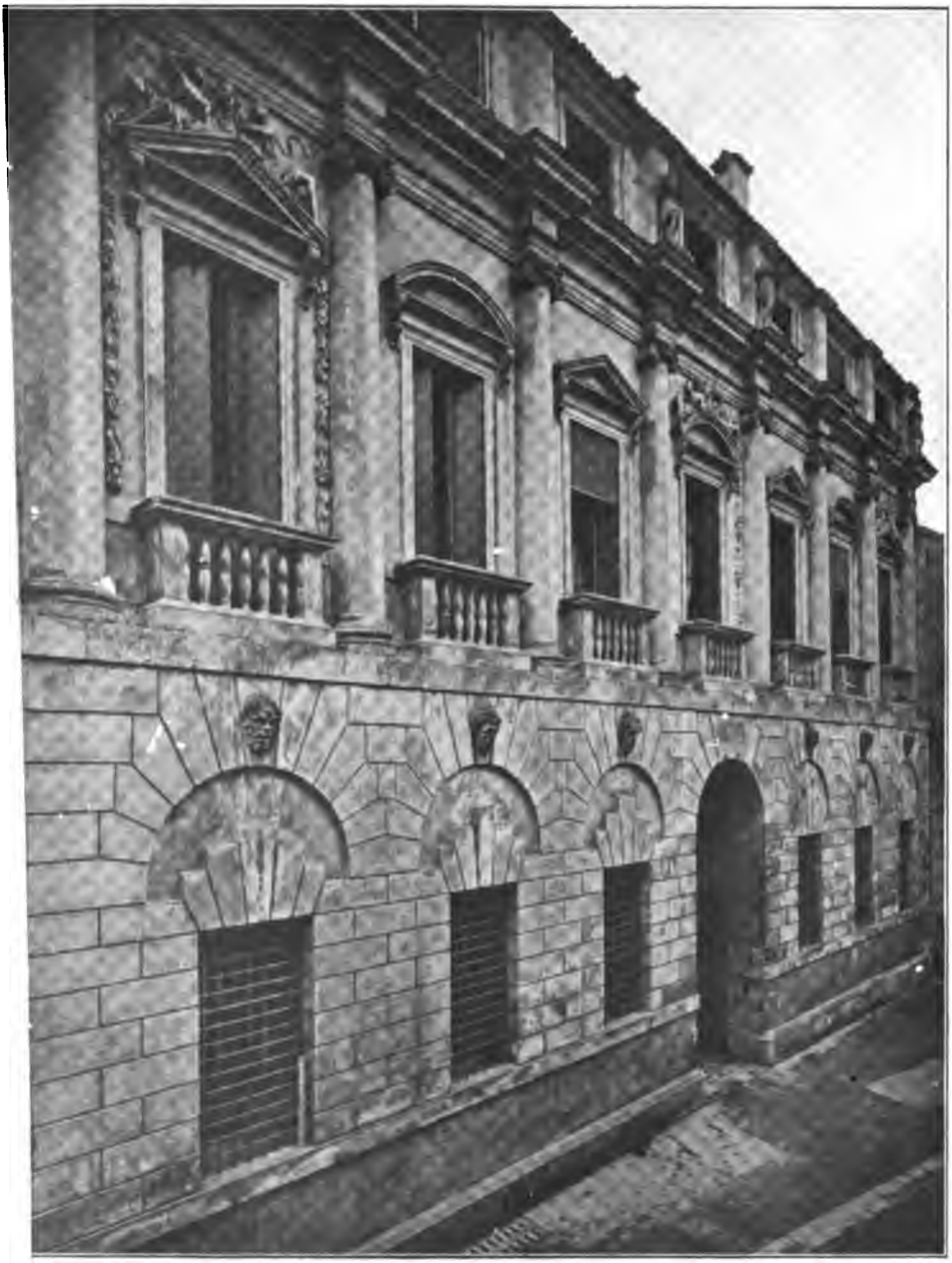

SVPERPOSITION
TVSCAN OVER ARCADE
1 Em
3 Em 65
92.5
30
55
1 Em 85
1 Em 50
3 Em
1 Em 80
4 Em
65
1 Em 5
70
3 Em 60
4 Em 80
1 Em 15
1 Em 65
1 Em 26
93
80
2 Em

Fig. 21.



Colleoni-Porto Palace, Vicenza, Italy; Andrea Palladio, Architect.
A Renaissance example of the placing of an Order above an arcade.

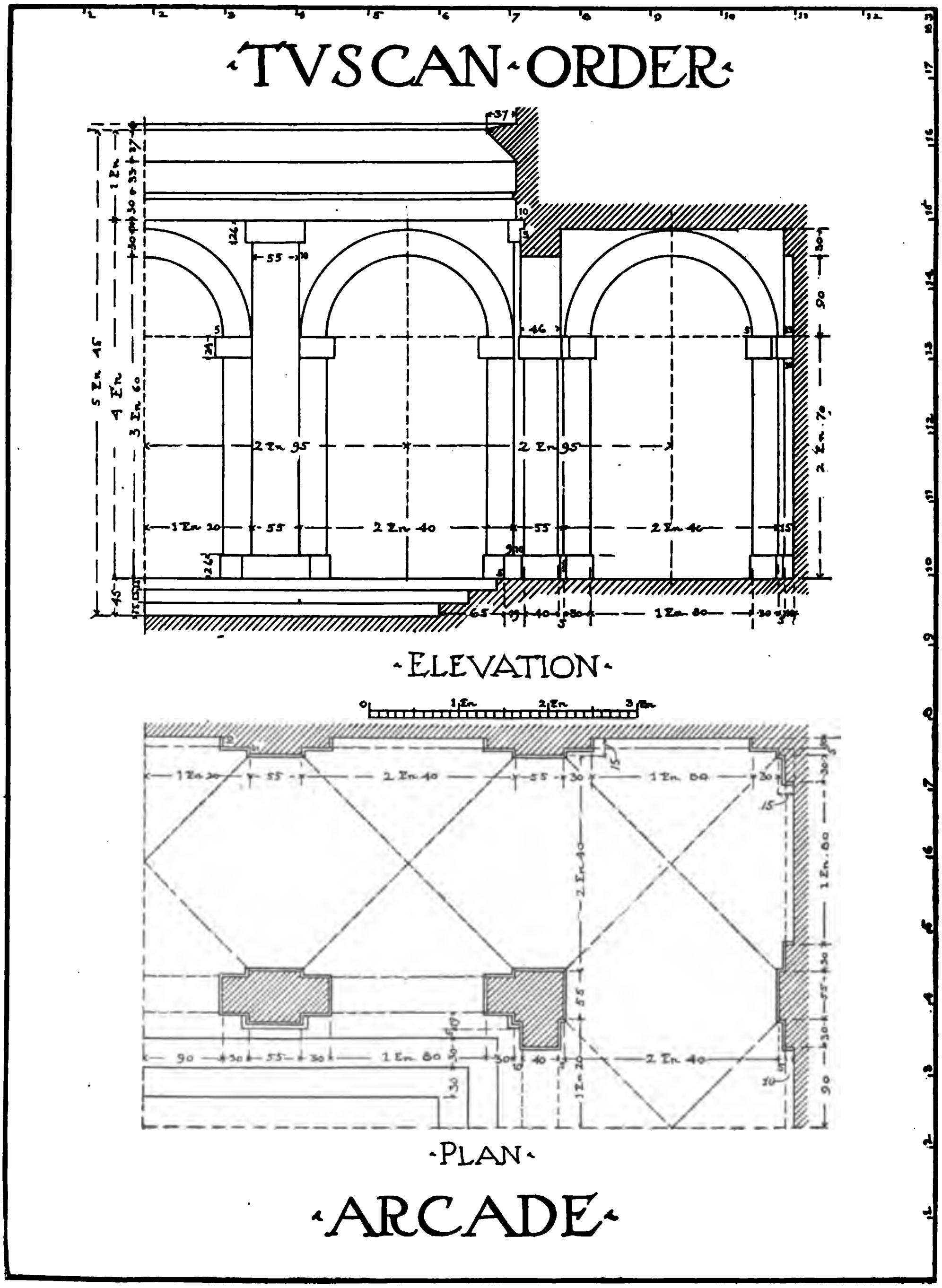
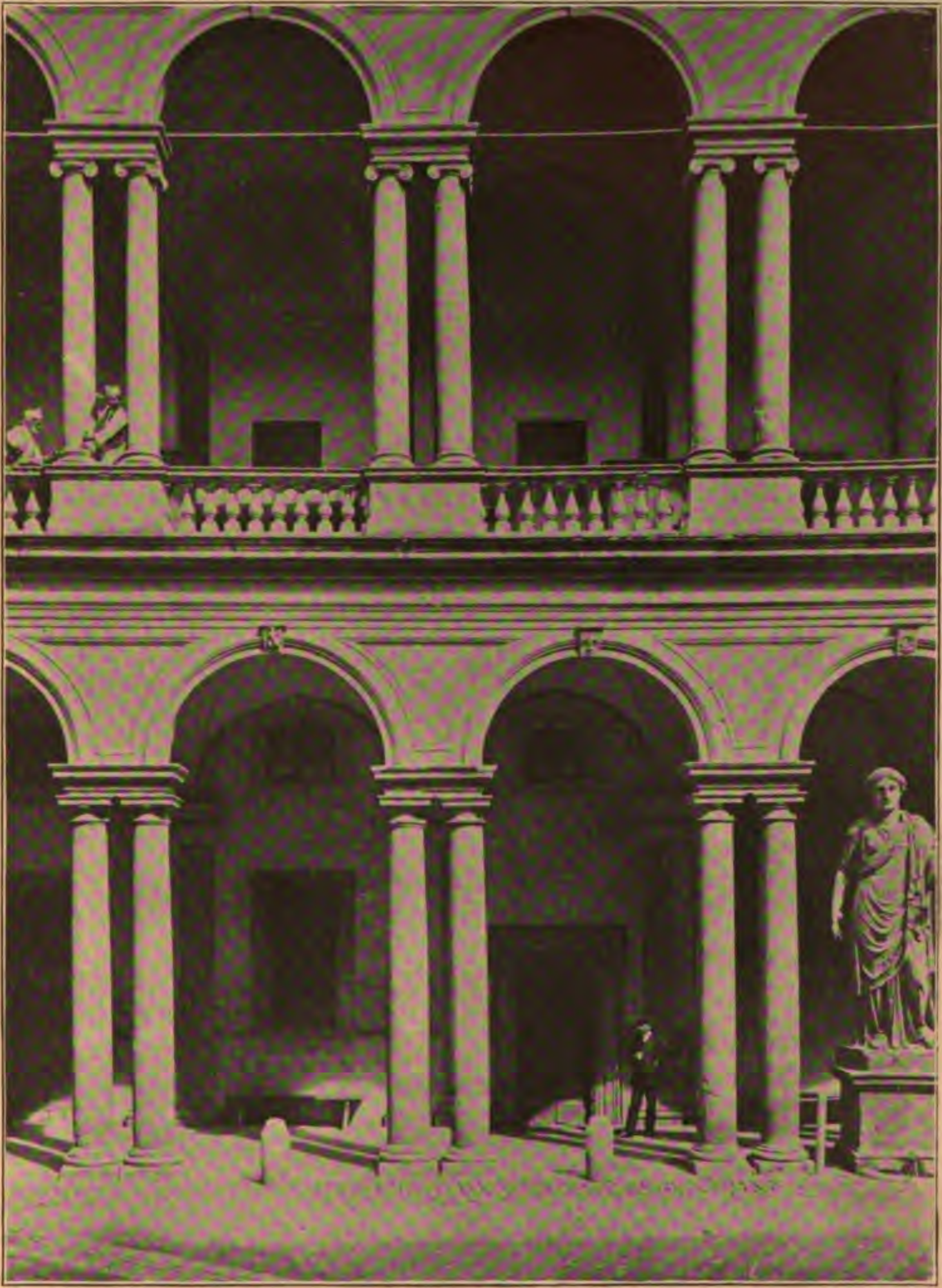


PLATE XXIII.

(A reproduction at small size of Portfolio Plate XXIII.)



Detail of Courtyard, Borghese Palace, Rome; Martino Longhi, Architect.
Showing Renaissance superposition of arches resting on coupled columns.

117. It sometimes happens that the same order is employed in two different stories, in which case the upper example should be more slender and of less diameter than that below. This rule holds good for any superposition of the orders. Usually the base diameter of the shaft above is the same as the diameter at the neck of the shaft below. In section, or in side elevation, it is the practice to make each order recede slightly from the face of the one below. In other words, the base or square plinth beneath the column in the upper story should be plumb with the face of the frieze of the order of the story below. This gives an appearance of stability which is quite appreciable and prevents the upper orders from seeming to overpower and overweigh the orders below.

118. If columns are coupled and set exactly over each other, there is slight tendency for the space between the columns in the upper story to seem too wide. This may be avoided by taking the center line of the space between the lowest couple and then draw the columns in toward each other on each successive story; keeping them in the same relation to each other and equally spaced on each side of the center line.

119. Facades of edifices of two stories sometimes have an order occupying the whole height of the upper story, the lower story being treated as a pedestal for this order. An example of this combination is seen in Fig. 21. The lower story or ground floor, raised on three steps, is composed of an arcade crowned by an entablature to which may be applied the details of the Tuscan order. Above this entablature is a Tuscan or a Doric order with arches whose axes correspond to those of the lower arches. This order is raised on a double plinth which forms the base of the arcade.

120. The use of an order in the upper story of a two-storied facade offers few difficulties and generally produces a good effect; the proportional height of the base to the order which surmounts it depends entirely on the height of the stories. In this plate the height of the ground story of the facade has been assumed to be six entablatures of the second-story order.

121. The succeeding plates offer an opportunity to study the various methods and combinations in which columns attached to a wall, and called "engaged columns," are used. Such columns were much employed by the ancient Romans in a manner which modern architects have frequently imitated. The engaged columns form a projecting part that in certain instances adds greatly to the perspective effect of a facade, and sometimes serves also as an additional support; but in many instances pilasters would be preferable, especially on the angles of a building. The columns are generally engaged in the walls for from one-third to one-quarter of their diameter.

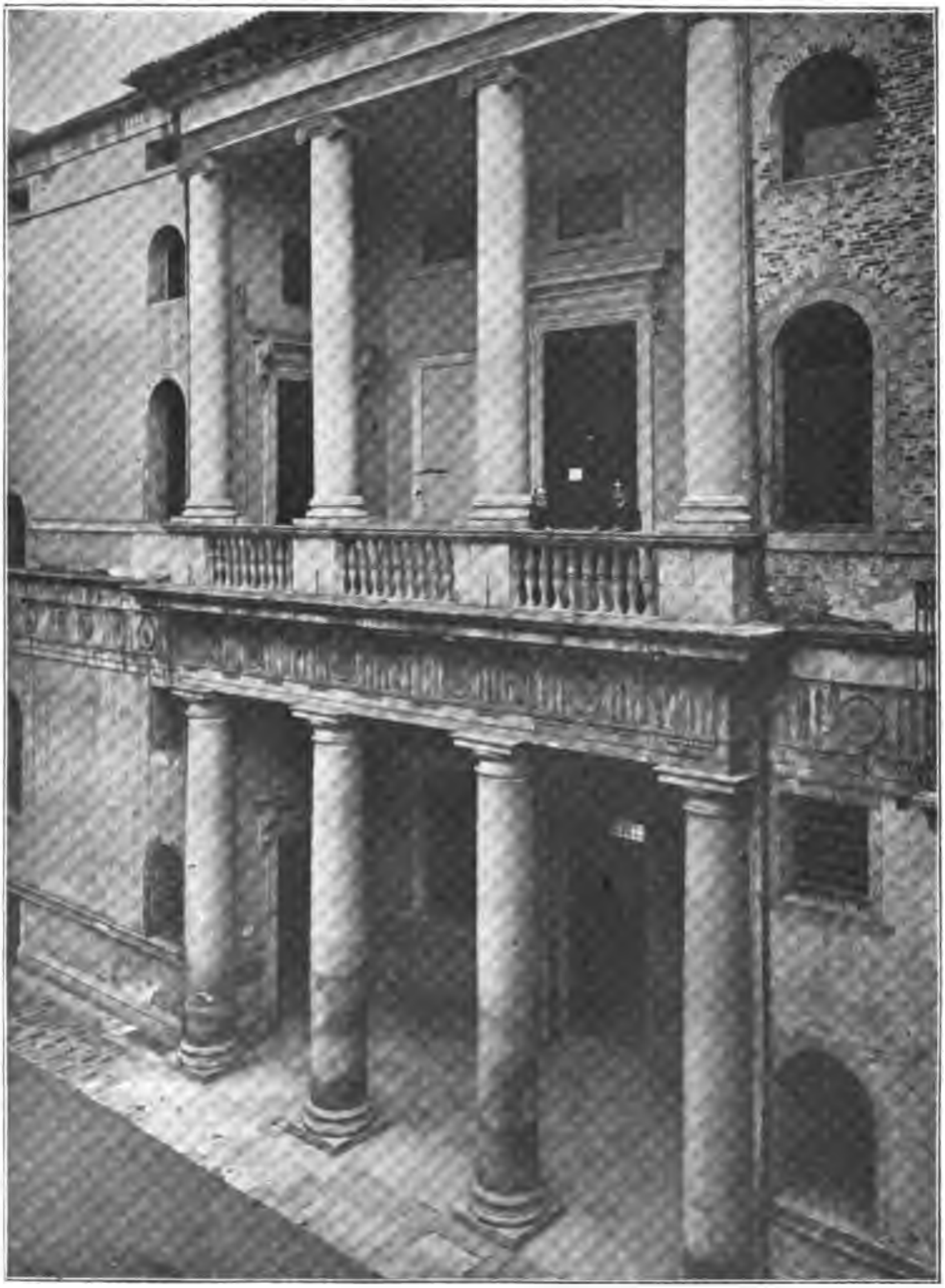
122. The Romans have also left famous examples of superposition of the orders in the facades of their theatres and amphitheatres, although such a combination is not considered as effective as an order superposed on an arcade, as in Fig. 21.

123. It has been explained that the lower order in a superposition should be a little larger than the one next above it. In Fig. 22 the height of the upper columns is three entablatures seventy-five parts of the lower order, whose columns are four entablatures in height (as is shown by the figures at the left-hand margin).

The same rules have been observed in the two exercises that follow. The Ionic order, placed above the Doric in Fig. 23 is a little smaller than the Doric; the height of the column being but three Ens seventy-five parts of the lower order. The Corinthian column placed on the Ionic in Fig. 24 has but three Ens seventy parts of the height of the Ionic. This will give in each instance for the column of the upper order a lower diameter that is substantially the same as the upper diameter of the column over which it is placed. At the same time the height of the second story, as well as the arches and column there used, is reduced proportionally, unless the column shafts be attenuated beyond the rule here employed

124. Taking the height of three entablatures and seventy-five parts of the first story order, for the total height of the columns in the second-story order in Fig. 22 by re-dividing that height into four parts, it is easy to ascertain the height of the second-story entablature in relation to the column with which it is used.

125. In elevation it will be seen that the piers of the second story (Fig. 22) are not as wide as those of the story below,



Chieregati Palace, Vicenza, Italy; Andrea Palladio, Architect.
Detail of courtyard façade, showing Renaissance use of Ionic over Doric Order, both being of exceptionally refined and Classic proportions.
(Compare with detail of Theater of Marcellus opposite page 194.)

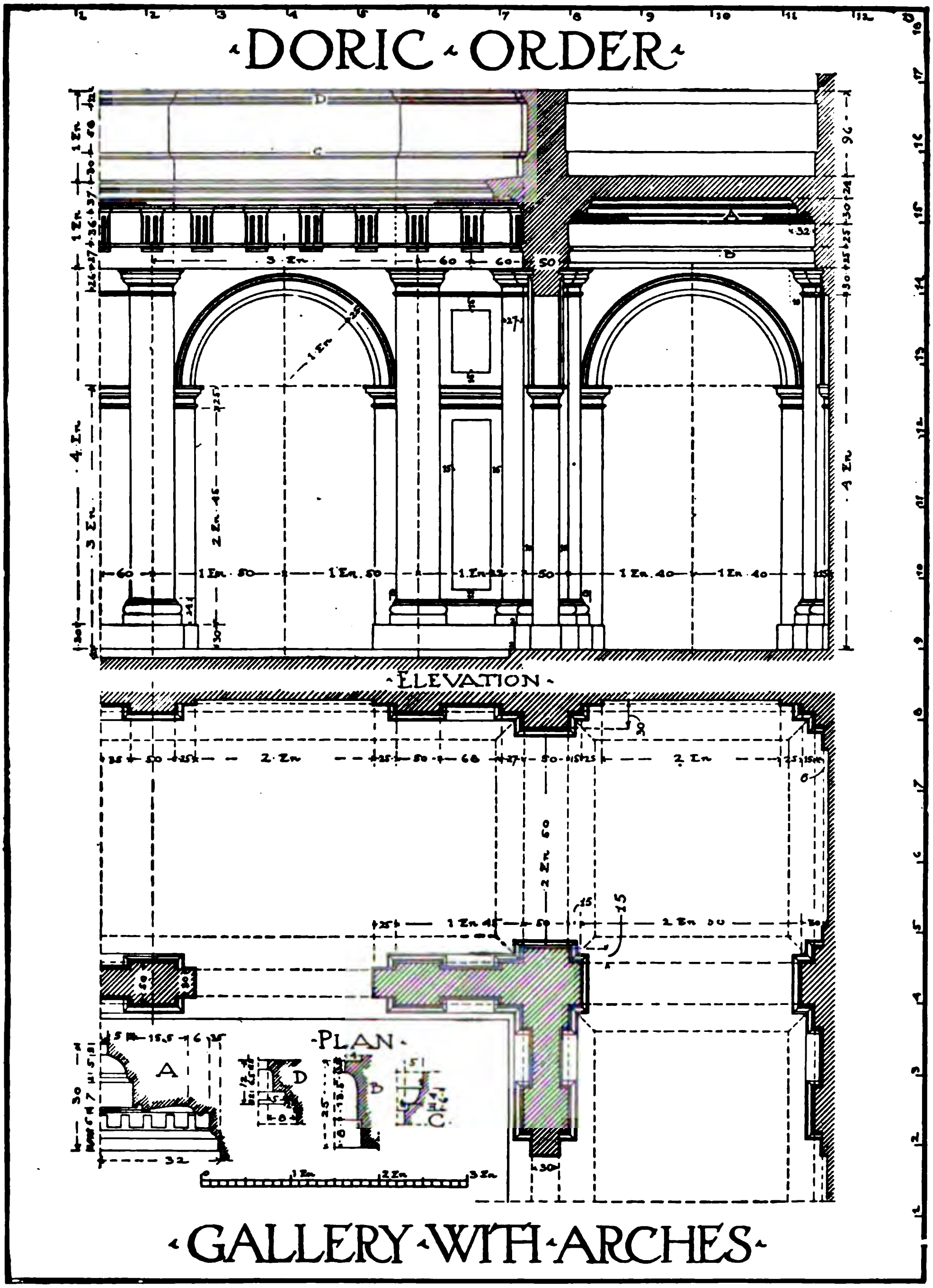


PLATE XXIV.

(A reproduction at small size of Portfolio Plate XXIV.)

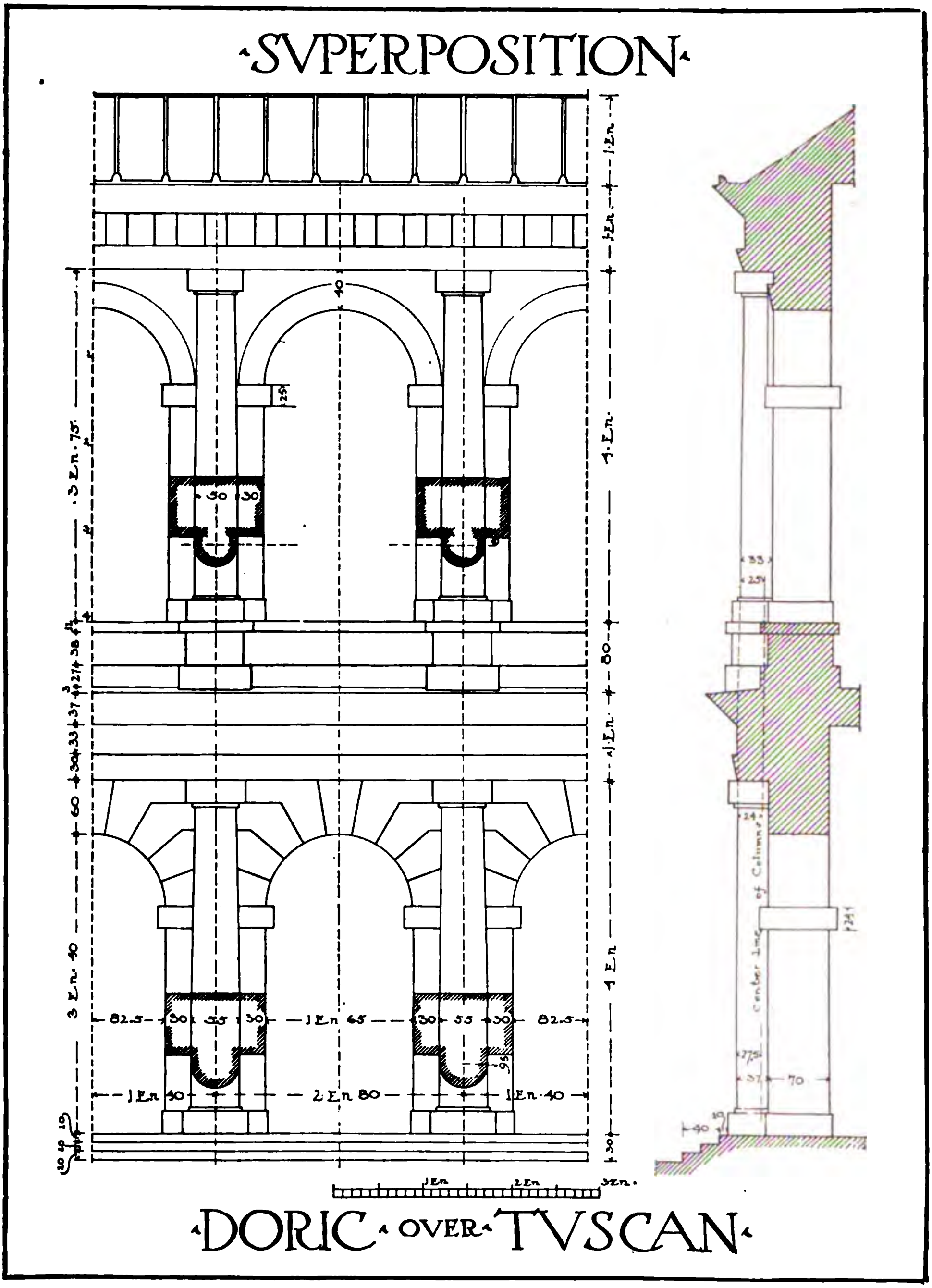

SVPERPOSITION
DORIC OVER TVSCAN
1 En
1 En
4 En
3 En 75
80
1 En
4 En
3 En 40
60
30
30
50
30
82.5
30
55
30
1 En 65
30
55
30
82.5
1 En 40
2 En 80
1 En 40
25
95
33
25
24
27.5
37
70
40
10
Center line of Columns
1 En
2 En
3 En

Fig. 22.

by an appreciable amount. Although the figures given show a difference of only five parts, it must be remembered that the unit employed in the upper order is smaller than that used in the lower story, and therefore the difference is somewhat more than that which the actual figures suggest.

126. By referring to the section (Fig. 22) it will be seen that in this example the second-story column shaft at the base, lines with the frieze and column shaft at the neck of the order below, while the second-story pedestal and column base project beyond this line. This arrangement allows the center line of the second-story column to be over the center line of the column below.

127. In Fig. 23 another method is followed; here the face of the pedestal or die of the second-story order is placed in plane with the frieze and column neck below, when it becomes impossible for the center line of the columns to coincide; there being, as shown by the dotted line in the section, a difference of eight parts between these center lines.

128. In Fig. 24 again, we find that the base of the shaft of the second-story order lines with the neck of the shaft below.

129. Where a pedestal is given to a second-story super-imposed order, except under exceptional circumstances, the method shown in Fig. 23 would probably be most certain of making a favorable impression upon the observer, although it might be possible that a compromise between the methods shown in Figs. 23 and 24 would better solve the problem. Such a question must be decided by the judgment of the designer. It might be said, however, that where the second-story column is placed upon the entablature of the first-story order without the interposition of a pedestal, the best effect would invariably be obtained by directly lining –in section—the face of the foot of the second-story column shaft with the face of the neck of the shaft below.

130. The facade shown in Fig. 22 is composed of two rows of super-imposed arches, one of the Tuscan and the other of the Doric Order, each pier carrying on its face an attached column shaft.

The Doric Order is raised on a support forming a pedestal and having a cap and base.

131. Fig. 23 is a facade of two stories, with the Ionic Order placed over the Doric Order. The columns are engaged in the

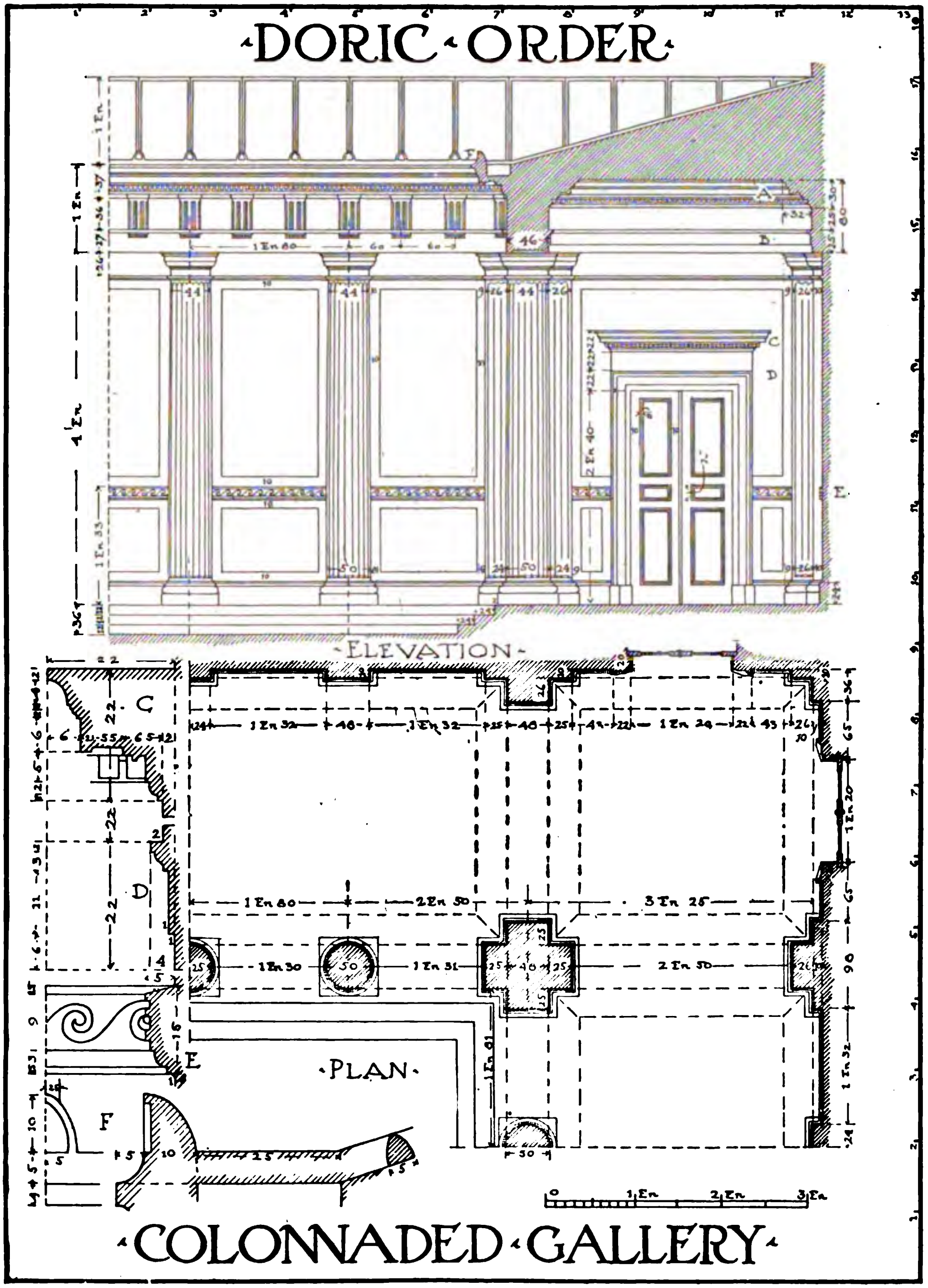


PLATE XXV.
(A reproduction at small size of Portfolio Plate XXV.)

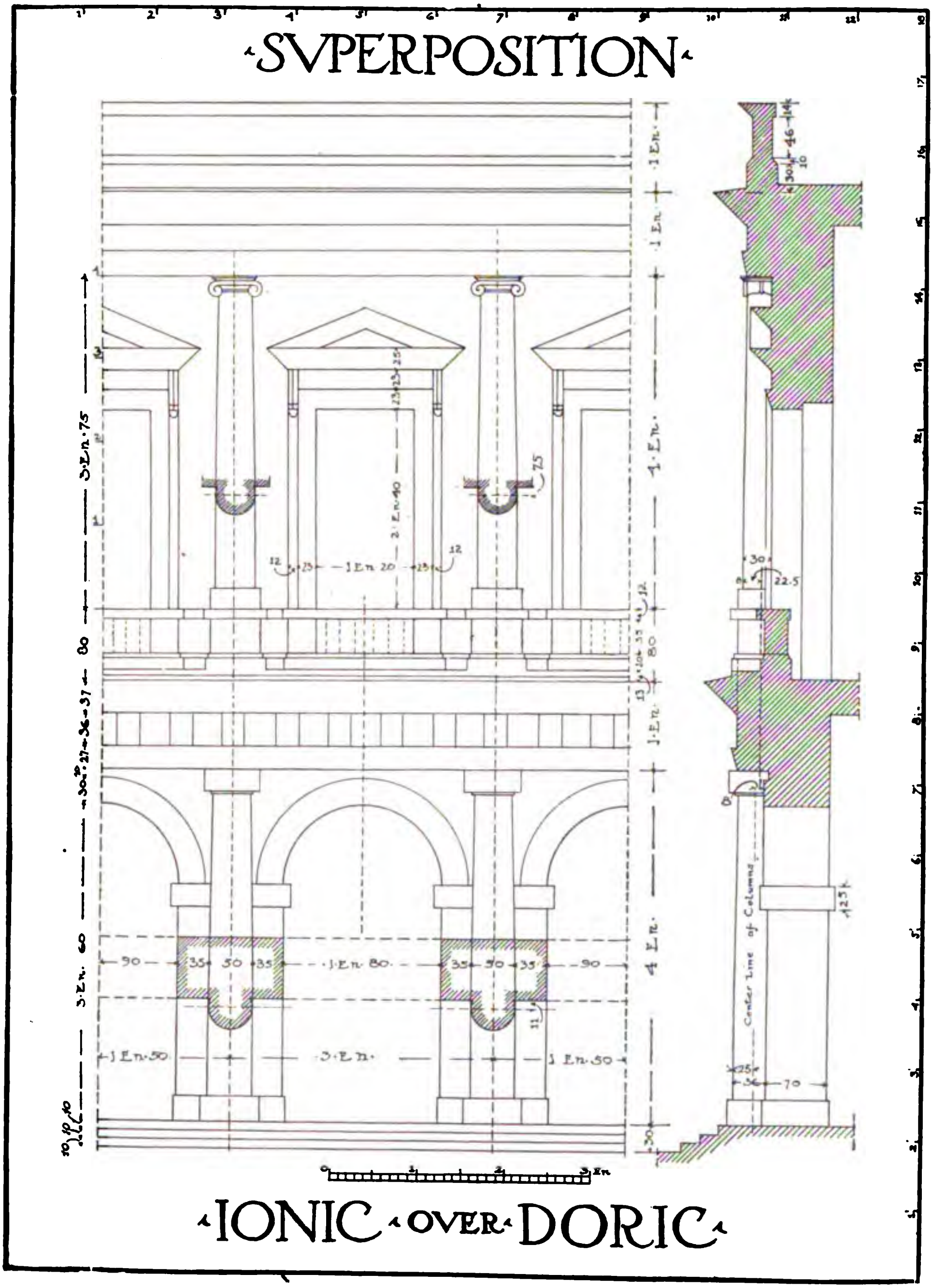

SVPERPOSITION
1·En·
3·En·75
80
4·En·
3·En·60
2·En·40
1·En·20
35
50
90
1·En·80
1·En·50
3·En·
30
22.5
Center Line of Columns
70
IONIC OVER DORIC

Fig. 23.

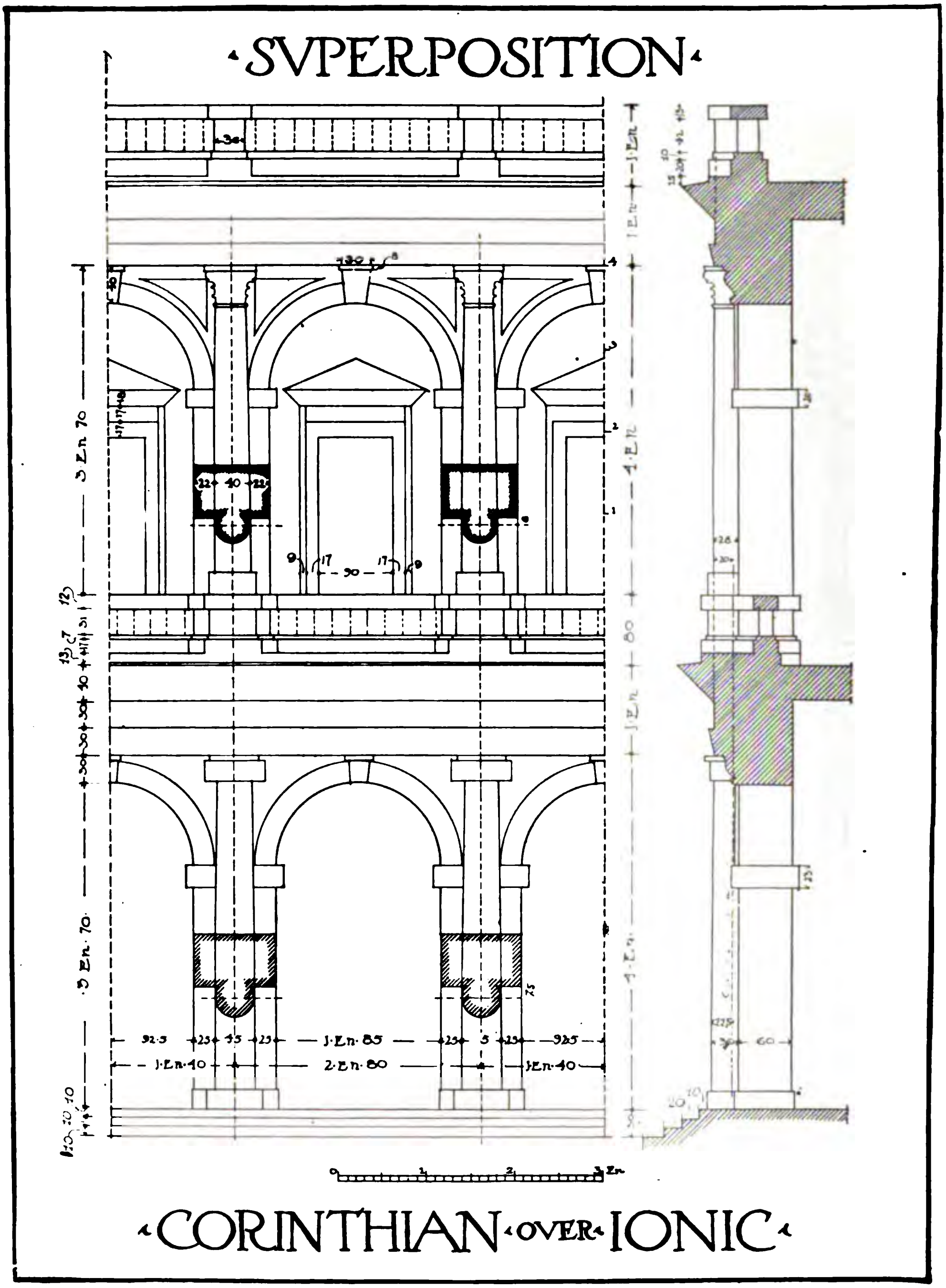
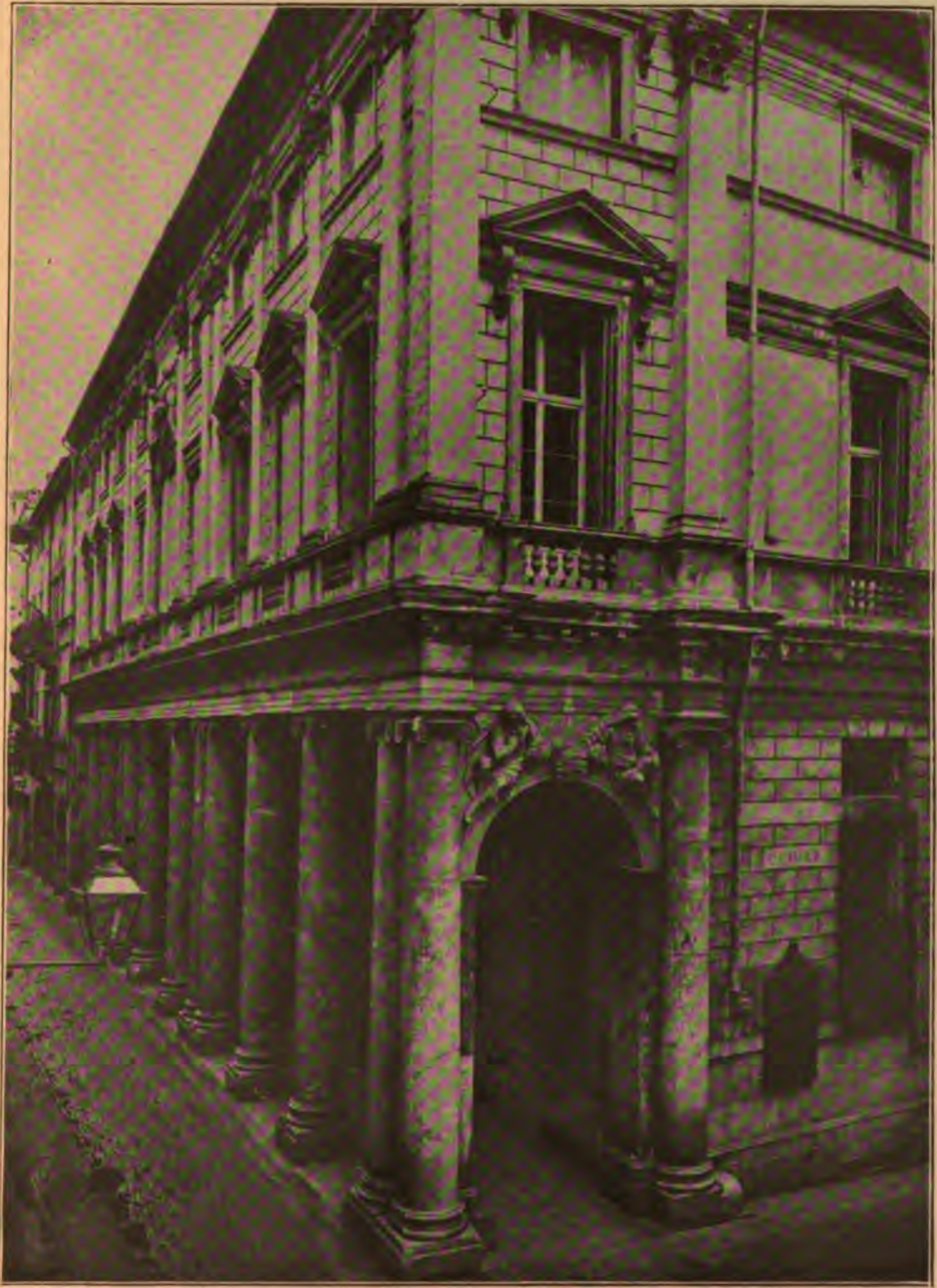
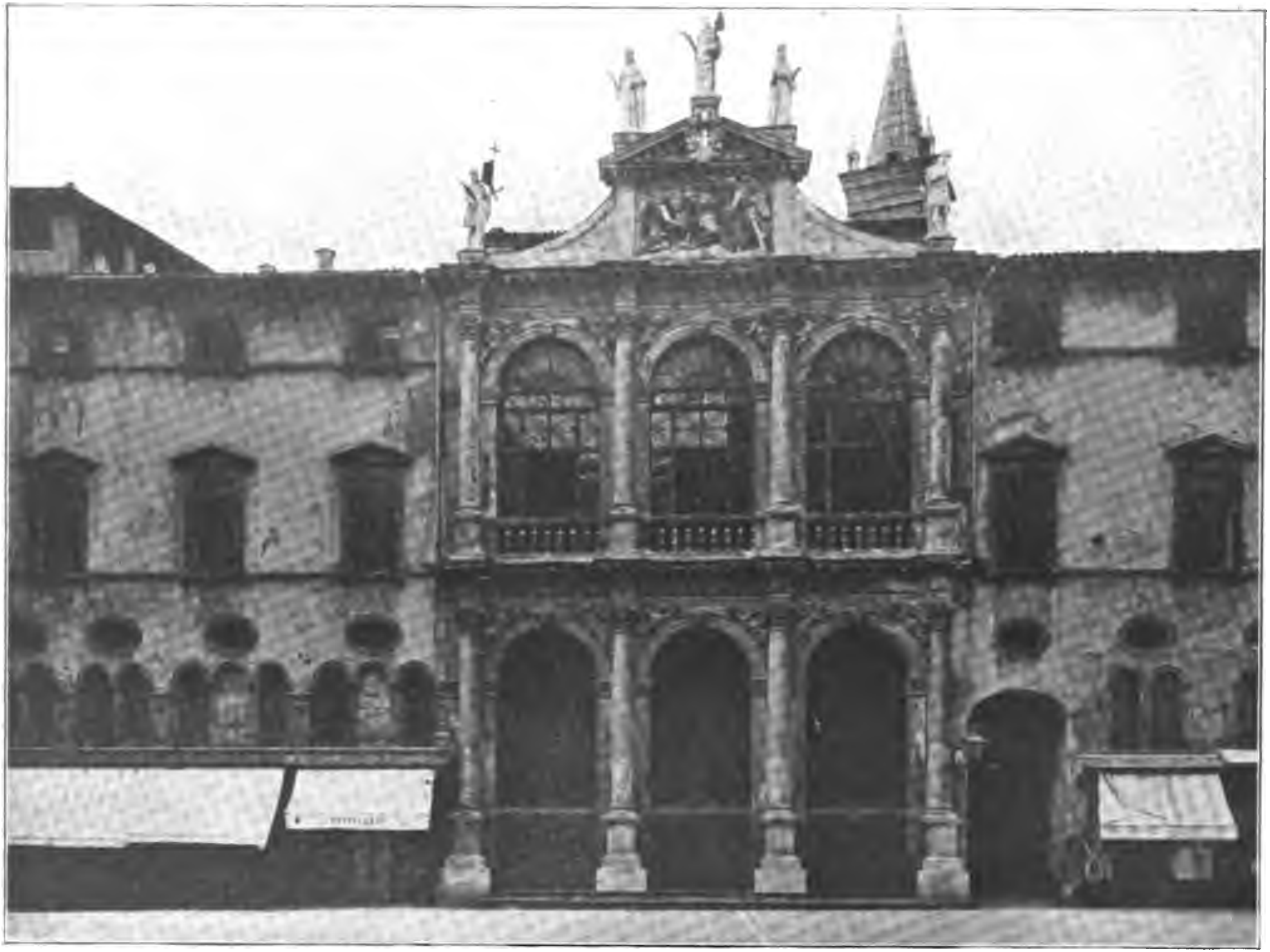

SVPERPOSITION
3·En 70
1·En
4·En
80
1·En 40
2·En 80
1·En 85
1·En 40
CORINTHIAN OVER IONIC

Fig. 24.



Porto Palace, Vicenza, Italy (1588); Vicenzo Scamozzi, Architect.
A Renaissance example of the use of Composite pilasters over an Ionic colonnade.



Façade of Church of San Vicenzo, Vicenza, Italy (Fifteenth Century).
A Renaissance example of the use of arcades and columns after the Roman manner, the Composite Order being placed over the Corinthian.

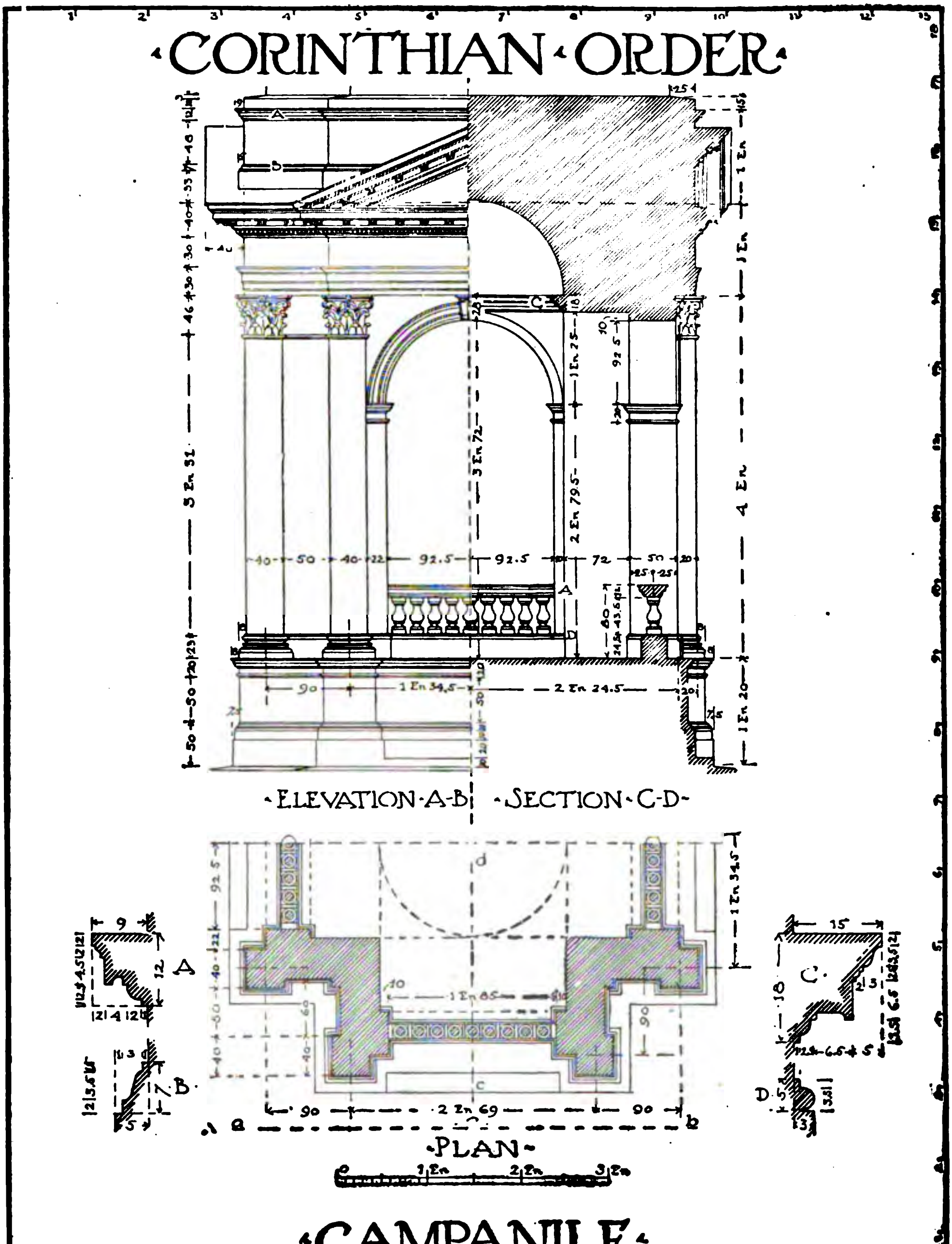


PLATE XXVI.
(A reproduction at small size of Portfolio Plate XXVI.)

wall which is pierced with arches between the lower columns, and with rectangular windows between the upper columns. The windows are ornamented with frames or architraves with an outer pilaster finish carrying consoles, the whole being surmounted by an entablature with a pediment. The details of these parts should be taken from the examples of similar details shown in Plate XXVIII.

The support or pedestal of the Ionic Order forms a balustrade in the bay of the window.

132. In Fig. 24 is shown a section of a facade of two stories where the Ionic Order is used with the Corinthian above it. The columns are placed between arches, forming an arcaded gallery. The windows shown are found in the wall at the back of the gallery, and the upper entablature is surmounted by a parapet wall or balustrade.

EXAMINATION PLATES

133. The student who has followed closely this analysis with its application, will have an intelligent knowledge of the Orders, and may put his knowledge to practical use in the exercises which follow.

IN GENERAL.

In laying out, from the descriptions and plates, the various problems which follow, some differences from the proportions already given may occasionally be found. These differences, in all cases attendant upon some ethical reason or principle of the problem involved, must be understood by the student before he attempts to apply the theoretical knowledge of the orders already acquired. Then, from the general dimensions given to determine the proportions of the problems, he will find it possible to complete the design by the application of the various details shown in the preceding plates. These exercises require the application of what the student has previously learned, to actual—if academic—problems, while they will also serve to illustrate such details as the proportions of arcades and openings, and the spacing of columns and of piers.

134. These exercises must be drawn out in pencil before inking in any parts of the drawing. The plan is the prime essential and should be first determined and drawn out. In starting a drawing, either in plan or elevation, the general principles given in paragraphs 5, 6, 9, 10, and 11 should be observed. The center line or axis must first be established in order to determine the relation and the placing of the drawing upon the paper.

135. The dimension figures given throughout these exercises may be omitted from the drawing; but all the lettering, both large and small, must be included. The plate must be signed and dated in the lower left or right-hand corner, and sent to the School for correction and criticism. The plates must be taken up and drawn out in the order given and the first plates submitted when three are completed in order that the student may profit by the instructor's corrections as he progresses with his work.

The Examination for this Instruction Paper consists of fifteen plates, which should be sent to the School in six instalments:

1st Instalment	A, B, and C,	4th Instalment	I, J, and K,
2nd "	D and E,	5th "	L and M,
3rd "	F, G, and H,	6th "	N and O.

Each Instalment should be sent as soon as completed.

The paper for these plates should be purchased in sheets 22 inches × 30 inches. (Imperial size). Some of the plates are to be 11 × 15 inches (¼ of Imperial size) with border line ½ inch inside, making panel 10 inches × 14 inches. Others are to be 13 × 18 inside of border line, for which use ½ an Imperial sheet; while a few will require the whole sheet and should be 20 inches × 28 inches inside of border lines.

PLATES A AND B.

136. These exercises are shown in Fig. 4 and Plate II respectively. Fig. 4 should be drawn to the size shown in the margin, each unit representing one inch. Therefore the finished plates will be 10″ × 14″ in size. Plate B should be an accurate copy of Plate II. Leave out dimensions.

PLATE C.

137. The sheet of mouldings shown in Fig. 5, is to be redrawn on a plate whose border line is 10″ × 14″. The names of the mouldings with the general title of the plate should be lettered in, following as closely as possible the model illustration.

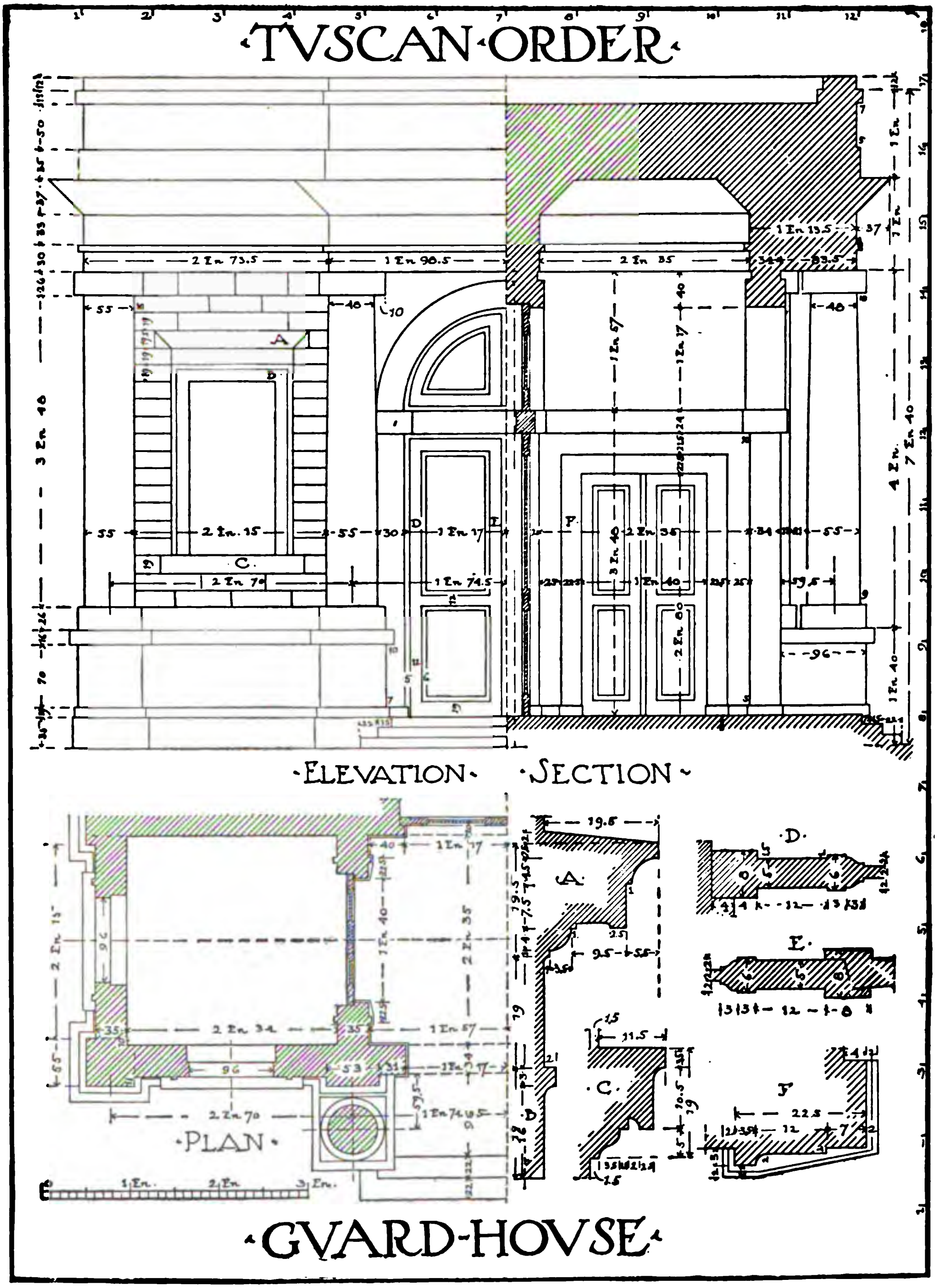


PLATE XXVII.
(A reproduction at small size of Portfolio Plate XXVII.)

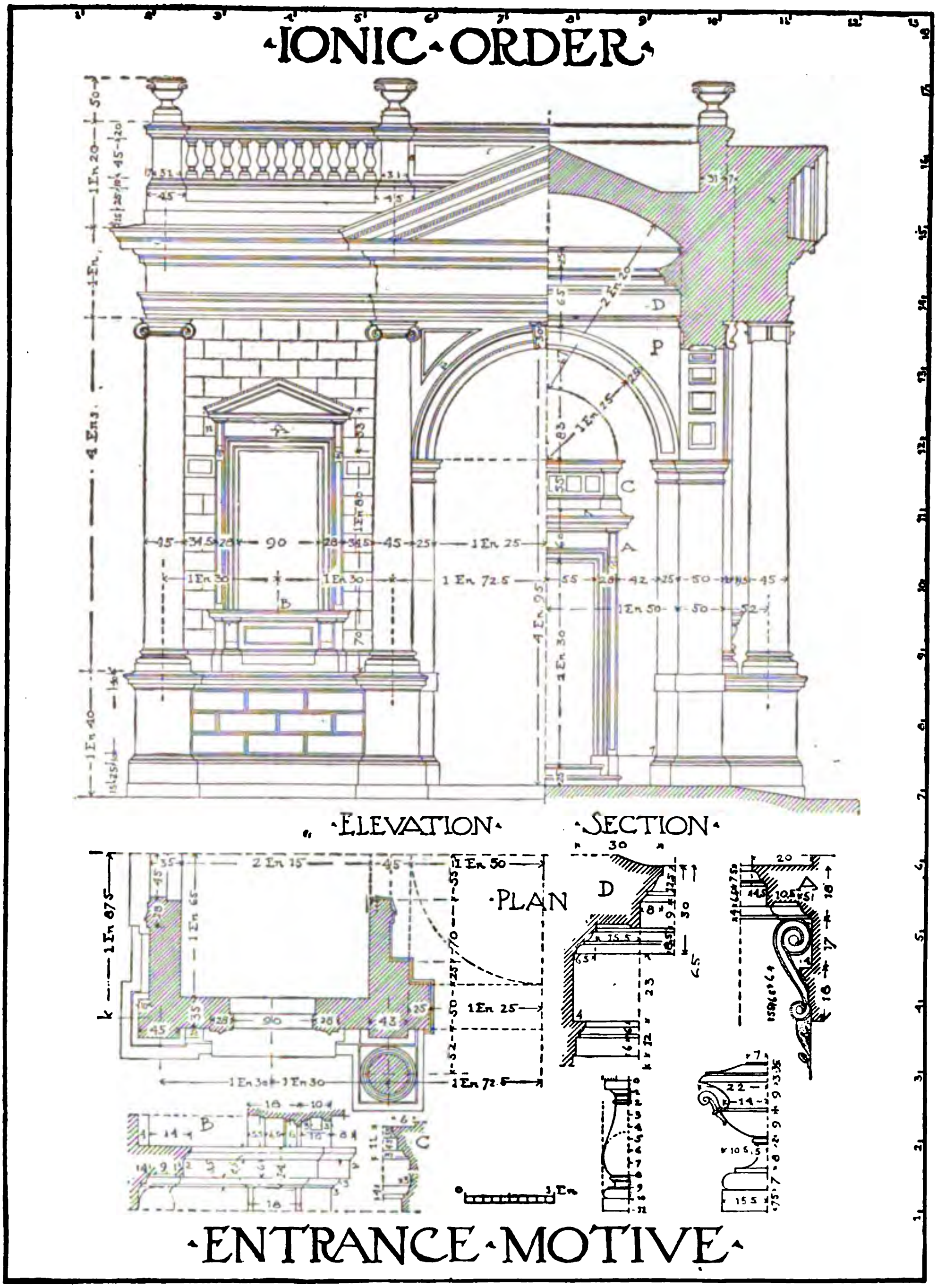


PLATE XXVIII.
(A reproduction at small size of Portfolio Plate XXVIII.)

PLATE D.

138. Draw a plate to the border-line size of 10″×14″ and arrange after the manner shown in Plate VIII, assembling the various details of the Doric Order shown in Plates III, IV, V and VI, and following the measurements for the separate parts therein given. The placing of these details on the plate, with their relative size, lettering, etc., is to be as shown in the model, Plate VIII. Either the Mutular or the Denticular Order may be drawn out, as the student may prefer.

PLATE E.

139. The Ionic Order is to be drawn and the finished plate is to correspond in appearance and arrangement with the model, Plate XIII, and is to follow the construction and proportions given in plates X, XI and XII.

PLATE F.

140. The Corinthian Order is to be drawn so as to resemble the model, Plate XXI, and is to follow the measurements, proportions, etc., of Plates XVII, XVIII and XIX. Plates XV and XVI should assist materially in understanding the method of drawing the Corinthian capital shown in Plate XVII.

PLATE G.

141. The arched doorway of the Denticular Doric Order, shown blocked out in rough outline in Fig. 25, is to be drawn to follow the general dimensions, and to include all the details given in the plates of that order. The border line should be 20×28 inches in size.

The width of the archway is two and one-half entablatures, and the columns, from center to center, are three entablatures and sixty parts apart. The heights, and the placing of the plan and elevation on the plate, will all be easily ascertained by following the inch units shown against the border line, Fig. 25.

PLATE H.

142. The archway of the Ionic Order shown in Plate XXII is to be redrawn with the same outline size as in Plate G. The width of the Ionic arch is two and one-quarter entablatures, and

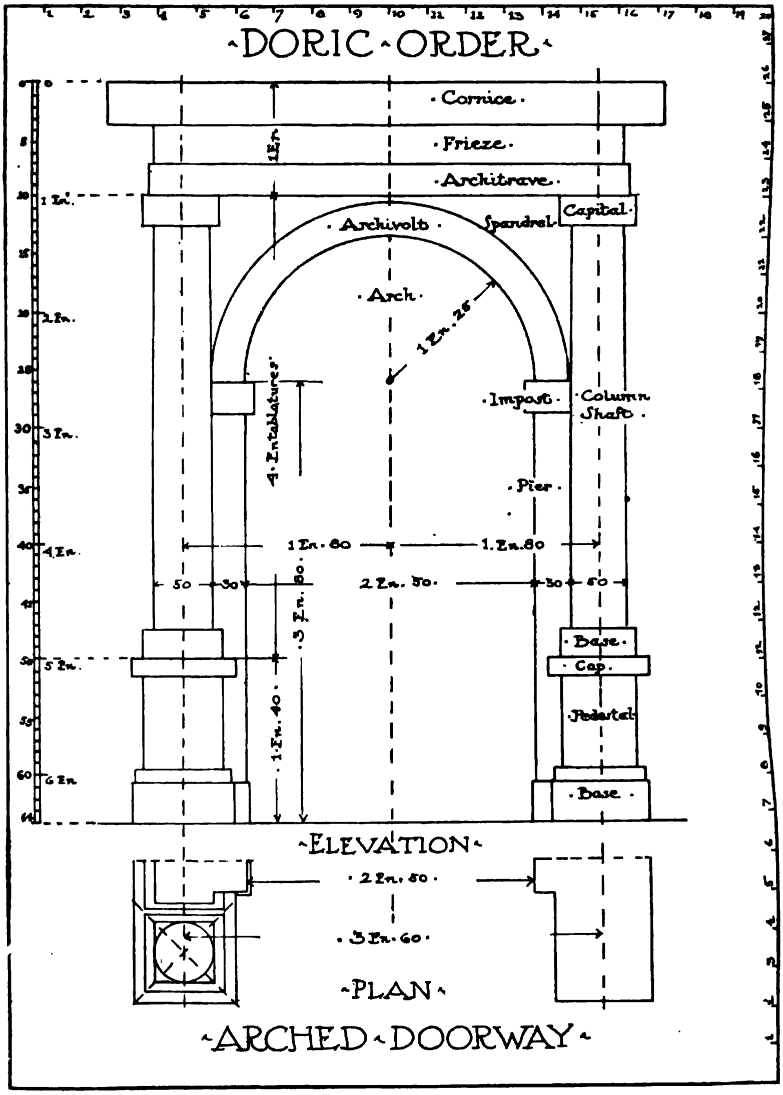


Fig. 25.

its height is equal to twice its width, an accepted general rule for proportioning arches. The archway is ornamented with two columns placed before pilasters, which are in turn set against the face of the piers.

Apply to this exercise all the details of the preceding studies in the Ionic Order and draw out, as shown in this plate, the plan, the half elevation, and the section.

PLATE I.

143. As an application of the study of the Corinthian Order, draw out an archway similar to that of the Ionic Order just described. The drawing should show a plan, section, and half elevation, but should follow the proportions and dimensions given in the plates of the Corinthian Order. The columns are spaced about 3 entablatures and 40 parts and the center of the archivolt is occupied by a keystone ornamented with the console shown in Fig. 16.

This problem is exactly like the problem of the arched doorway in the Ionic order except for the fact that the proportions and details are those of the Corinthian Order. The distance 3 En.-40 from center to center of the columns is the only dimension given for this plate. The student is expected to obtain all the other necessary dimensions from his study of the preceding plates.

144. In drawing this problem, which will be on a smaller scale than the Corinthian Order plates drawn before, the student should pay particular attention to the proportions of the parts. Some little difficulty may be experienced in laying out the smaller members. While at such a scale it may seem impracticable to draw these members in their true relative size, still, the general proportions of the details of the order may be clearly indicated, if carefully studied and drawn. The sheet should be 20″×28″. This size is given so that the student will experience as little difficulty as possible with the smaller members and still have the drawing of a convenient size. Begin by drawing a vertical center line and on each side of this lay out the center lines of the columns.

PLATE J.

145. This exercise requires that the student use the Tuscan Order shown in Fig. 6, and the details shown in Plate II. This order is required because it will be found easier to use in these early problems on account of the large scale of the mouldings and the few lines required in their delineation. It is to be drawn out to the size of 13″×18″ and is to follow in appearance and arrangement, Plate XXIII. On this plate the plan is completely shown, while the elevation is merely blocked out in the rough, in order that the student in completing it may have independent practice in the use of the order.

This problem displays the inner corner of a square or rectangular court yard, which is surrounded by an arcade composed of the Tuscan pilaster and archway. The floor of the gallery is raised three steps of fifteen parts each, above the level of the court.

146. The gallery is vaulted with semi-circular vaults; that is, vaults whose form is a semi-circumference. A vault formed of a semi-circular arch, without penetrations throughout its whole length, is called a barrel vault. Two vaults of the same radius which intersect each other form what is called a groined vault, because of the hips or groins which mark their intersection. The vaults over this gallery are barrel vaults, which, by their intersections at the angles as well as by the penetrations of the barrel vaults which correspond to the arches of the gallery, form groined vaults. The dotted diagonal lines on the plan show the groins of the vaults. The width of the gallery is two entablatures and forty parts, this width being equal to the distance between the pilasters of the facade. The groined vaults are separated by a space of fifty-five parts, that is, a distance equal to the width of the pilaster.

PLATE K.

147. This exercise is to be drawn out at the same size as the one just given, 13″×18″, and the plate numbered XXIV is to be accurately copied. The subject of this exercise is a gallery in the Doric Order with arches, surrounding a court or garden. The arches rest upon piers, decorated on their faces with a couple of pilasters spaced under alternate triglyphs. The space between the pilasters, occupied by the arches of the arcade, is determined by the spacing of the triglyphs, four of which occur over the arches. These pilasters are repeated in the interior of the gallery, which is covered by a flat ceiling, supported by an entablature whose details are shown on the lower portion of the plate. The ceiling over the corner is separated from that of the rest of the gallery by entablatures and arches resting on pilasters advancing

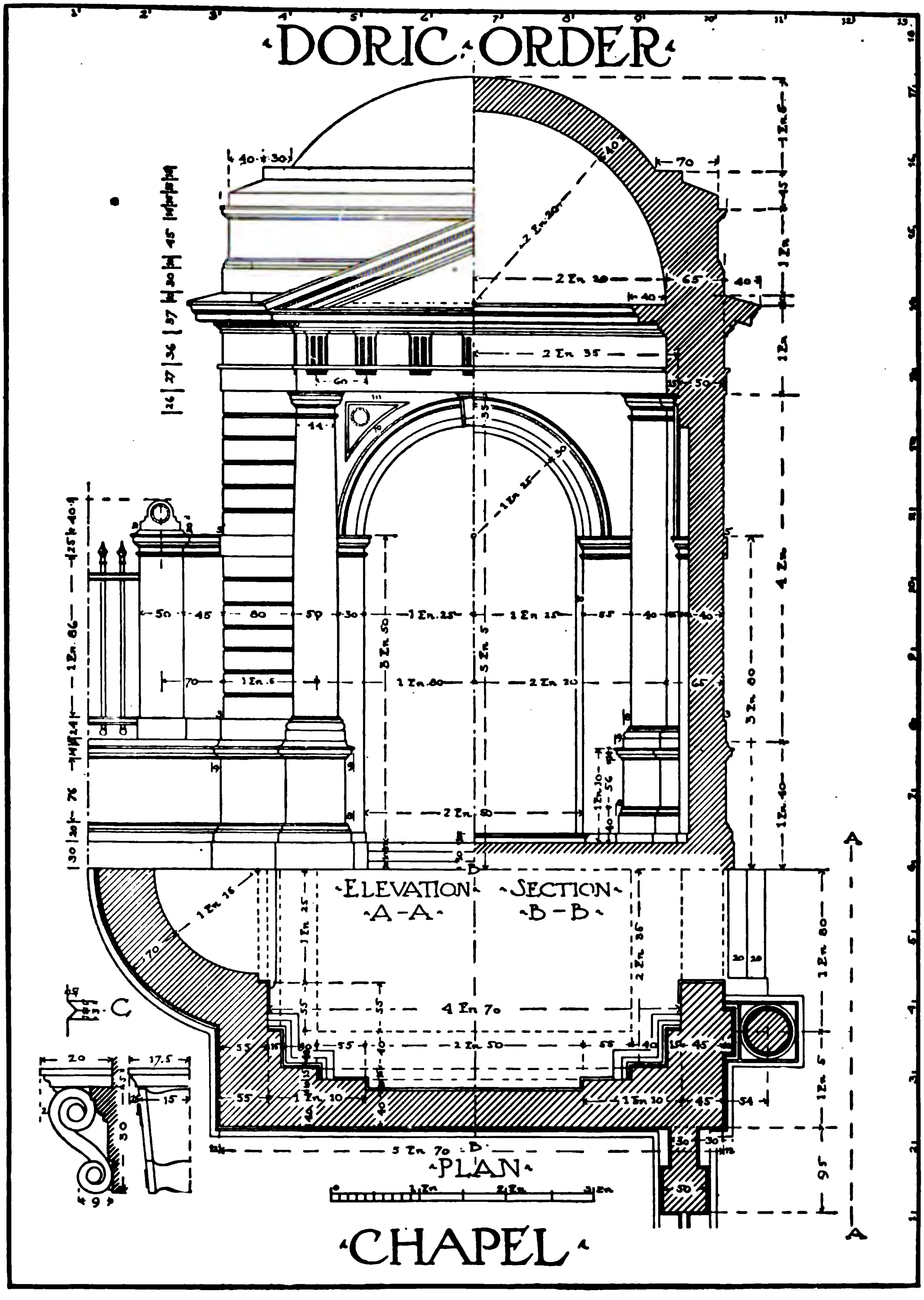


PLATE XXIX.
(A reproduction at small size of Portfolio Plate XXIX.)

from the faces of the corner piers. This combination is shown in dotted lines on the plan. The gallery arches are repeated on the blank wall which encloses the gallery. The exterior entablature is surmounted by a plain parapet or balustrade, as the roof of the gallery is flat and would be accessible from the second story of the edifice.

PLATE L.

148. This exercise is fully drawn out in Plate XXV, and should be copied by the student at the same size as the ones just preceding. In this example we have shown a gallery with colonnade; no arches being employed in the problem.

Here we have another possible treatment for a gallery surrounding a court or garden. It is that of a portico or colonnade, with a flat ceiling, the angles being strengthened by square piers, against each face of which a half pilaster is placed. This causes two pilasters to occur in line with the columns, and the other two to face toward the interior of the gallery, with two other half pilasters projecting from the surrounding walls, opposite them. The architrave of the connecting entablature forms a soffit between them, as the dotted lines of the plan indicate.

149. The surrounding walls are pierced by doors on the longitudinal axes of the gallery. These doors are surrounded by moulded architraves and crowned by entablatures or door caps. A wainscot, or dado, is formed by a string course ornamented with a Vitruvian scroll or wave (this is the term applied to the ornament whose detail is given on this plate at E). A plinth, or base, corresponding in height to the base of the column, runs around the walls; its crowning moulding being formed of the fillet and bead of the column base. The astragal of the capitals also continues around the walls, which, in addition, are decorated with panels intended to receive mural paintings. The flat ceiling, or soffit, of this gallery is similar to that of the preceding exercise and is supported or surrounded by the same entablature. The sloping roof is formed of sheets of zinc or lead corresponding in width to the spacing of the triglyphs, and with lips or rolls formed by the interlocking edges of the sheets. On the same axis with each lip is an antefix placed above the cornice, and shown in detail at F on this plate. In the cornice is formed a gutter for the removal of rainwater.

PLATE M.

150. The student is required to design an arcade and gallery using the Ionic Order. This gallery is to be similar in treatment to the one shown in Plate XXIII, where the Tuscan Order is employed. The plan of this gallery is shown in Fig. 26, while a perspective sketch of the spring of the arches on an interior angle is shown in Fig. 27. On the plan is indicated in dotted lines the form of the arching ceiling over this gallery. It is simply described as a barrel vault with the penetration from each side of arches of a less height and radius. The perspective sketch shows the method of treating the impost moulding on the interior, breaking it around the various pilasters forming the corner pier. On the exterior, the entablature is crowned by a balustrade composed of balusters similar to those shown in Plate XXXIV. The plan will give the width of the arched openings which, as we have already seen in other examples of the Ionic Order, are in height twice their width. This will determine all the remaining proportions of the exercise, which is to be drawn of the same dimensions as the preceding plates, 13×18 inches.

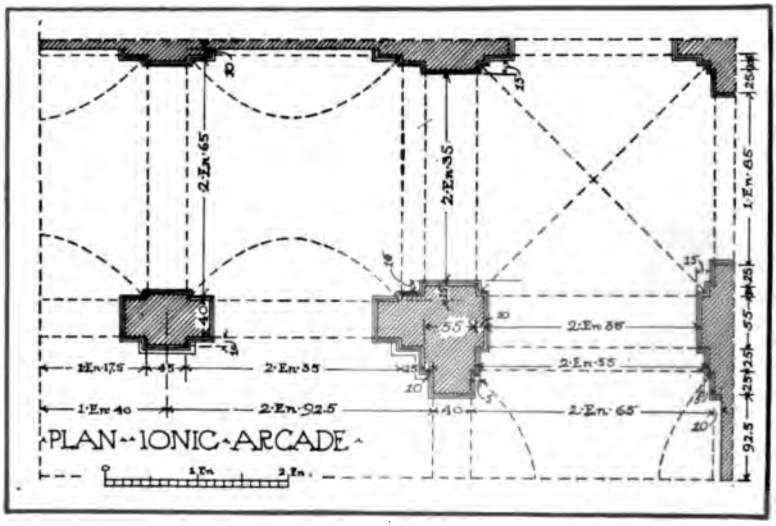


Fig. 26.

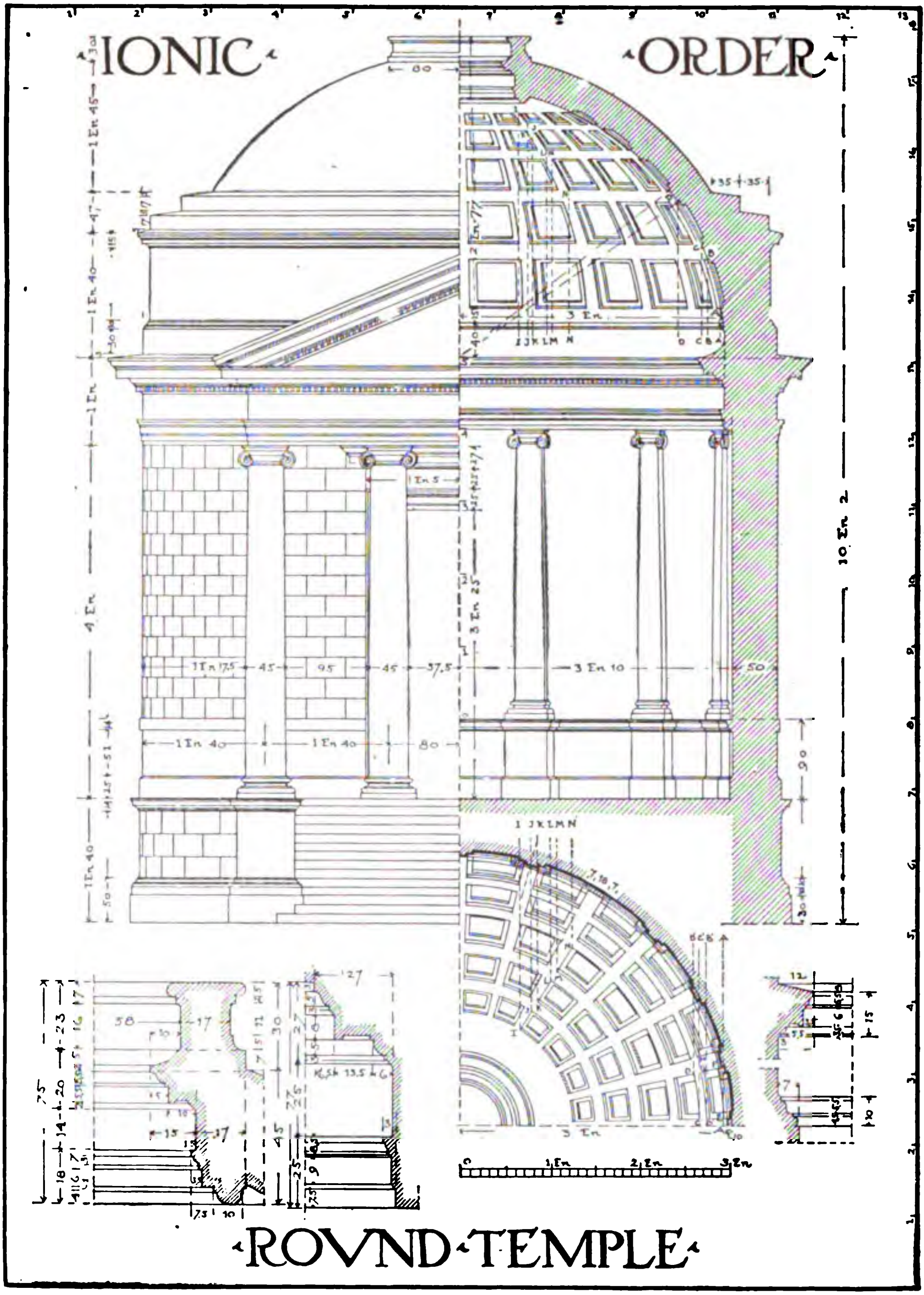
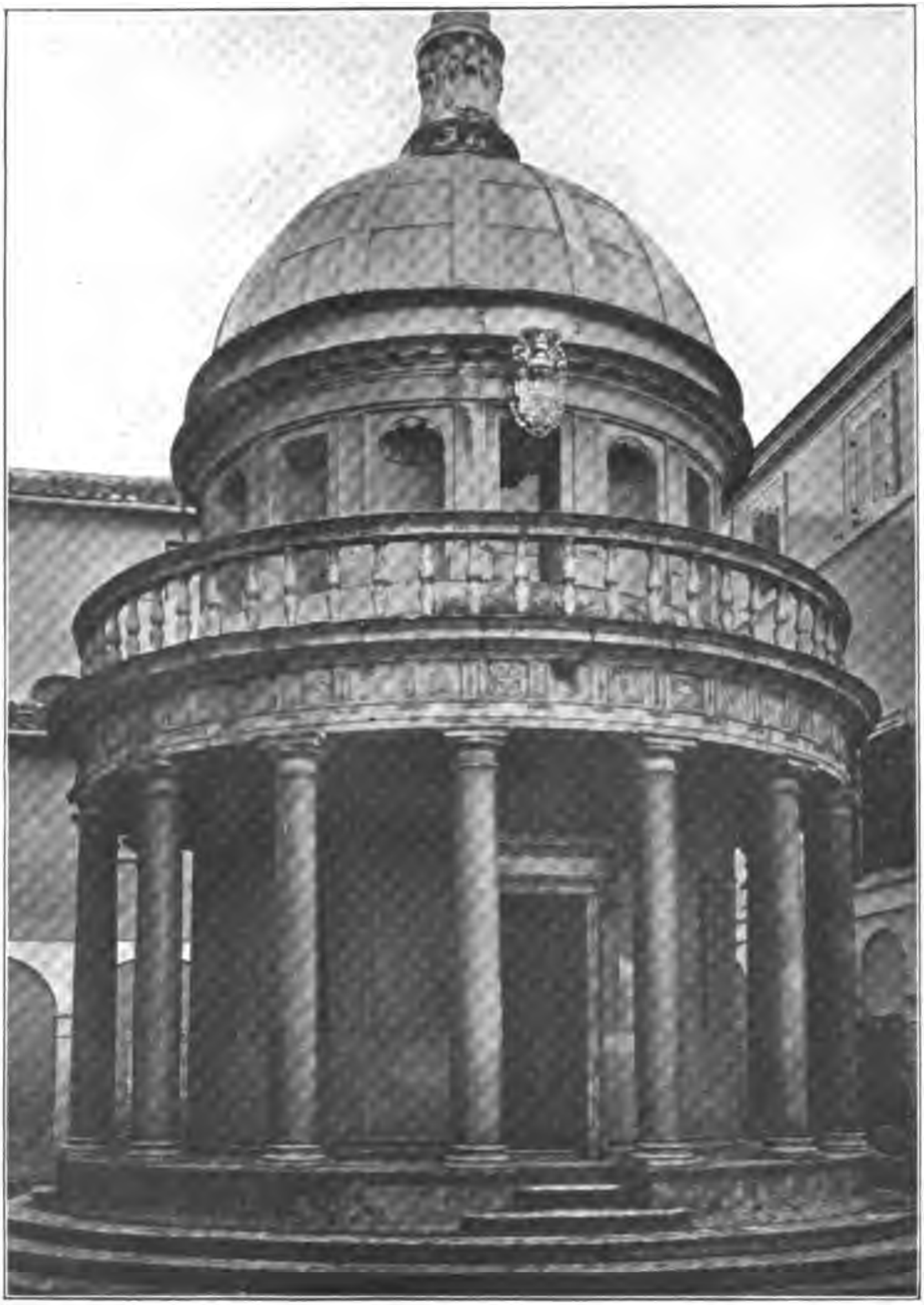


PLATE XXX.

(A reproduction at small size of Portfolio Plate XXX.)



Circular temple in Courtyard of San Pietro, Montorio, Rome; Donato d'Angnolo Bramante, Architect
Showing Renaissance use of Doric Order in a circular temple with domed lantern above.

PLATE N.

151. In Plate XXVI the Corinthian Order is used for ornamenting the final or crowning story of a Campanile or classic belfry. This problem is simply that of the arch placed between columns, which we have already seen in Plate I; the entablature being crowned with a pediment and such other modifications being made as the problem suggests. The student is required to draw out this plate at the same size as those preceding, 13″×18″, or if he desires he may substitute the Ionic Order and adapt its proportions and details to the same plan.

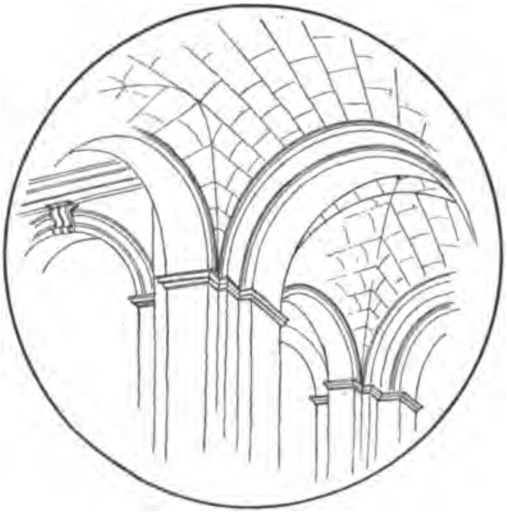


Fig. 27.

This upper portion of a Campanile may belong to a church, a city hall, or any other important edifice. The four facades are the same; each is composed of an arch flanked by two pilasters, carrying an entablature, a pediment, and a parapet. Each facade makes a projection from the mass of the tower. The four pediments penetrate the plain parapet which will, in turn, be surmounted by a roof or cupola. The interior is covered by a dome with pendentives (see paragraphs 157-158).

PLATE O.

152. Plate O is shown in Plate XXVII. This exercise requires merely the application of the arch and column of an arched doorway of the Tuscan Order to an actual problem; in this instance, arbitrarally termed a "guard house," the student is required to arrange his drawing on a sheet of the same size as in the previous example, and as shown in this plate. The plan and details being given, he must draw out the elevation.

153. The central part of the plan in this exercise is a porch, with arches, giving access by three doors to rooms placed on each side of the entrance, and to a hall or larger room at the rear.

154. We have called this problem a guard-house, because the disposition of the plan and the architectural character of the facade are well adapted to a problem of this character. The edifice may be completed by adding to its depth two pilasters or bays on each side, two entablatures and seventy parts (2 En. 70) apart from axis to axis; and in this way the lateral facade would be composed of three bays between pilasters, with an opening in each bay; the part added to the plan forms a large hall to which the door placed at the back of the porch gives access. This hall would then be lighted laterally by two windows on each side. The principal facade has a projection formed by two columns placed on pedestals and backed by two pilasters.

All the unanalyzed or new details of the Tuscan Order used in this exercise are shown at a larger scale on this plate. The interior entablature of this problem is the same as the exterior.

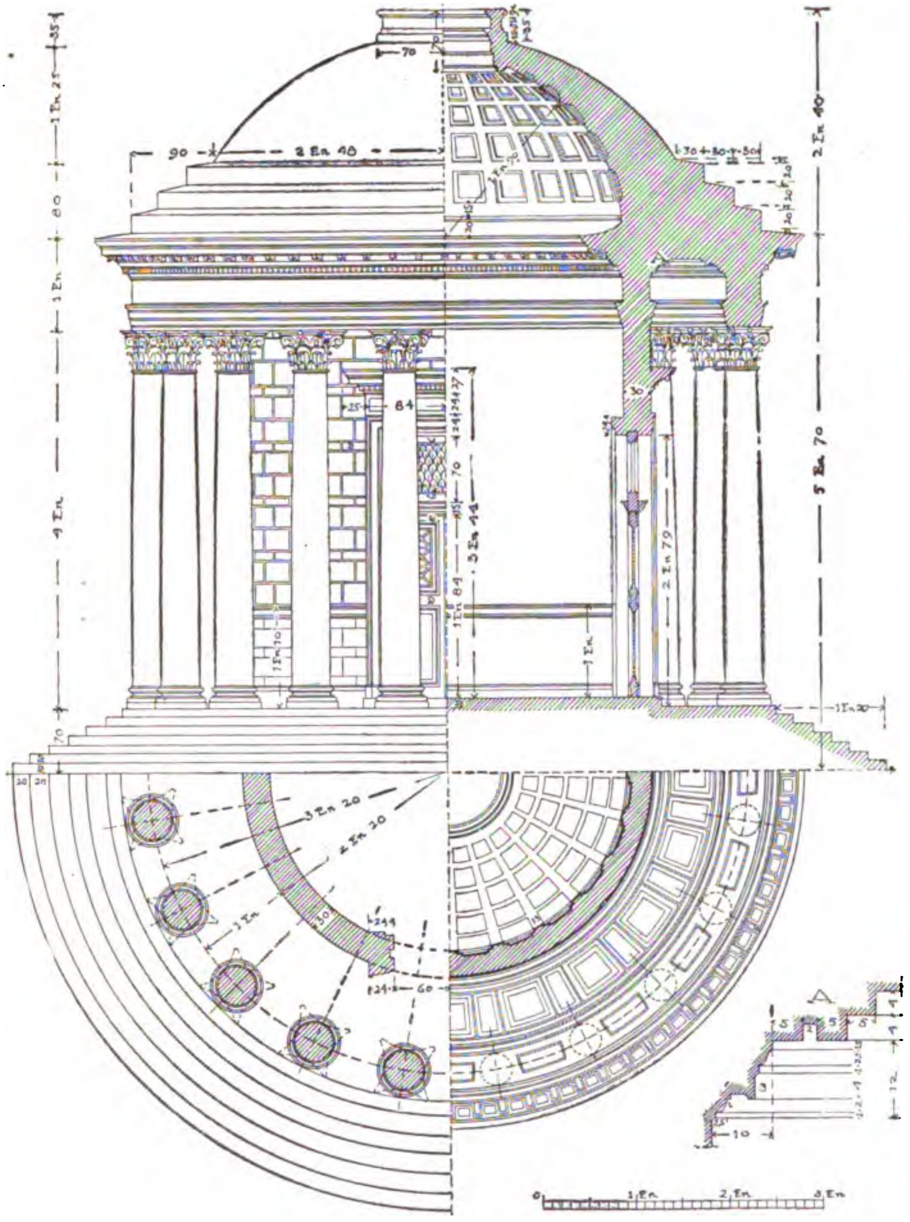
This concludes the required Examination: the remaining plates are given as a guide for students desiring to do further work by themselves.

PLATE P.

155. The entrance pavilion in the Ionic Order, shown in Plate XXVIII, is a problem similar to the one that has just been taken up. The student is required to reproduce this plate at the large size to which he has already drawn Plate O, with border line of 13×18 inches.

The small edifice is such as might be used at the entrance to certain public buildings, its plan—the same as that of the guard house—being composed of a porch with a room upon either side. One of these rooms might be the lodge for a porter, the other might be a ticket office. One quarter of the plan only is given as the arrangement is the same on the other sides of the axes.

CORINTHIAN ORDER



CIRCVLAR TEMPLE

PLATE XXXI.
(A reproduction at small size of Portfolio Plate XXXI.)

156. The front is composed of three divisions separated by columns or pilasters. In the center is the archway of the porch and at each side is a window whose sill is supported by consoles, and surmounting the outside frame are consoles of a different character which support the cornice and pediment. These details are shown in A, B and C on this plate. The same details may be applied to the door of the porch.

The windows at the side are similar to those on the principal elevation. The entablature is surmounted by a balustrade divided by pedestals carrying vases; the details of these balusters and of the vases are shown on this plate.

157. The porch is square in plan but has a ceiling or "cupola" in the form of a dome or spherical vault; that is, the ceiling has the shape of a segment of a sphere, whose radius is 2-En and 20 parts, as shown in the sectional elevation in Plate XXVIII. This kind of ceiling requires explanation. The ceiling must be supported on the walls of the porch, which is square in plan, but the domical ceiling is circular in plan; therefore a horizontal section of the porch at the point where the walls end and the ceiling begins will show a square for the section of the walls and a circle for the section of the ceiling. These two geometrical figures must be joined in some way so that the walls will support the ceiling and the ceiling cover all the space enclosed by the walls.

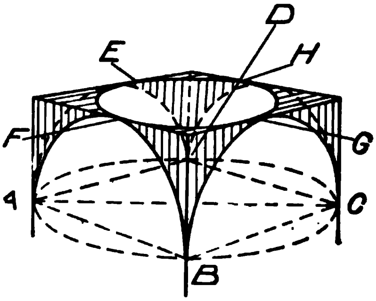


Fig. 28.

Whenever a square space is to be covered by a dome, the semi-diagonal of the square may be taken as the radius for the circle which forms the base or springing line of the dome. Fig. 28 shows at A B C D such a square and circle. If the four walls which form the sides of the square building are now continued upward, they will cut into the spherical segment whose base is represented by the circle, since this circle overhangs the square on all four sides. The figures cut from the domical surface by the walls will be segments of circles,—the intersection of a plane with a segment of a sphere. These segments of circles are shown in plate XXVIII as the semi-circular arches of radius 1-En and 50 parts, which cover the doorways. A horizontal section taken through the dome at the elevation of the crowns of these circular segments will show a circle which (in plan) will be inscribed in the square formed by the four walls, as shown by the smaller circle E F G H in Fig. 27. This circle is also shown dotted in the plan in Plate XXVIII.

The spherical surface which forms the ceiling of the porch has now been cut into, *first* by the four walls as they are continued upward from the springing line (A B C D) of the dome, and *second*. by a horizontal plane (E F G H) passing through the crowns of the four arches cut from the sphere by the walls. All that is left of the spherical surface is a triangular segment E D H in each corner. This portion of the ceiling is called the pendentive. In Plate XXVIII an elevation of the pendentive is shown at P.

158. The horizontal plane at the crowns of the arches cuts out from the spherical surface a circle (E F G H), which may now be covered over by a dome, or segment of a sphere, which may spring directly from it. In Plate XXVIII this circle is represented in elevation by the first horizontal line of mouldings above the arches. In this particular case, the domical ceiling or cupola does not spring directly from this circle but a small cylindrical band, or entablature, is built up above it for a height of 90 parts, from the top of which the ceiling springs.

PLATE Q.

159. The subject of this exercise (Plate XXIX) is a commemorative chapel of the Denticular Doric Order, and is to be drawn at the size indicated—13″×18″. This is the first of three exercises where a dome plays an important part in the exterior effect of an edifice. In any study, in elevation, of a building employing a dome or cylindrical story, it must be remembered that, in perspective, that portion which is circular in plan looks considerably smaller with reference to the square base from which it springs, than it does in any elevation,—on account of the difference in plan between a square, and a circle which is contained within such a square;—in other words, the circle remains of the same diameter if seen from any point; while an object square in plan, seen from any other position than in direct elevation, has its width considerably increased by the projecting corners.

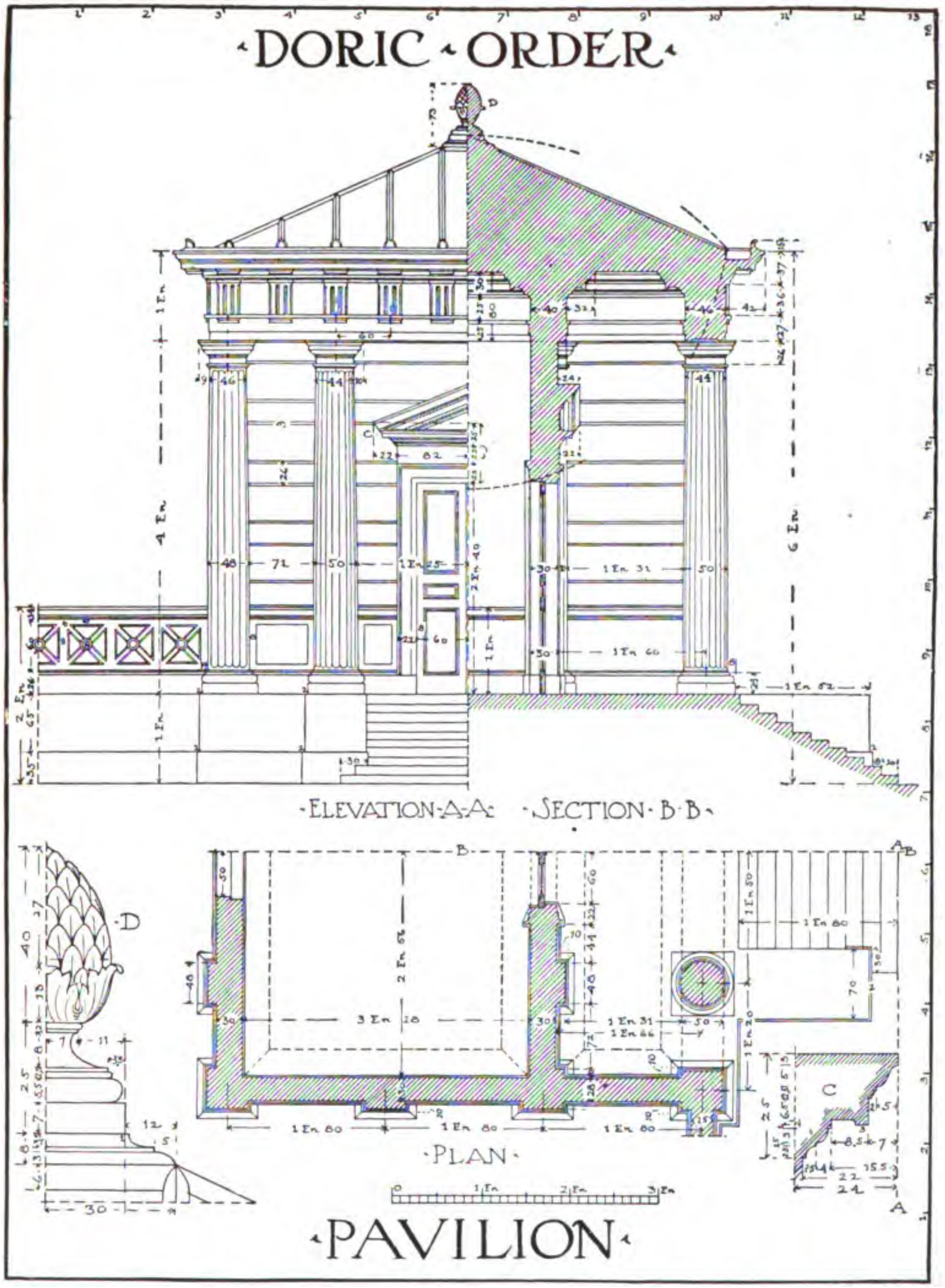


PLATE XXXII.
(A reproduction at small size of Portfolio Plate XXXII.)

160. The plan of the chapel is a square, having on the side of the principal facade, a projection formed by two columns placed upon pedestals and enclosing an arch whose proportions are like those of Fig. 25, this projection being crowned by a pediment. The opposite side has a semi-circular projection, in which is located a niche in which the altar may be placed.

161. The entablature surrounds the entire building, but the triglyphs are found only beneath the projecting pediment of the main facade. The building itself is surmounted by a low attic in the form of a plain parapet, above which are two steps forming a base for the domical roof.

162. The interior of the chapel is a square with its floor raised three steps above the exterior level. In the corners are pilasters forty parts in width and fifteen in projection; these pilasters, and also the entablature which surmounts them, are repetitions of the exterior order. The ceiling is a semi-circular vault or dome.

163. At the side of the facade is indicated the commencement of a retaining wall, with a grille, which might be continued to enclose a plot of land.

PLATE R.

164. Exercise R is a circular temple (Plate XXX, and plan Fig. 29) with a pedimented porch or portico, showing the use of the order set upon a dado around the interior walls. The ceiling is domical, with an opening in the center, and is ornamented on the under side by a series of recessed panels called caissons or coffers. This plate, like the one preceding, is to be drawn at the size of 13×18 inches.

165. Plate XXX shows an Ionic portico or porch attached to an edifice circular in form. The circular hall is six entablatures twenty parts in diameter, and the thickness of the wall is fifty parts. The perimeter of the hall is divided by pilasters of a smaller order than that on the exterior into twelve bays, as shown in the plan in Fig. 29. The difference in size is due to the pedestal, ninety parts in height, on which the pilasters are placed.

The scale for this interior order is obtained by dividing the total height of the pilaster and its entablature into five parts (each part representing one entablature of the interior order).

166. This circular hall is covered by a spherical cupola or dome, divided into caissons or coffers, the drawing of which constitutes the most interesting part of this exercise; it will therefore be explained as clearly as possible. It is illustrated on Plate XXX.

167. The projection of the interior pilasters being ten parts (at the scale of that order) from the face of the wall, the interior diameter of the springing of the cupola is six entablatures. Draw a half plan of the cupola, dividing its circumference into twelve equal parts and then draw the radii; lay off on each one of these radii, outside the circumference, the profile of a rib and the two coffers one on each side of the rib, each eighteen parts wide, and the two coffers seven parts each and three parts in depth. Next draw in on the plan two semi-circles, one of three entablatures and three parts radius, the other of three entablatures six parts radius. Having thus established the whole profile of the springing of the cupola, draw from each division a radius to the center; then show above this plan, centering on the same axis, the section of the cupola, whose center will be found forty parts below the first horizontal course. This height of forty parts forms a congé with an astragal above the cornice. The cupola is divided into five rows of caissons whose height is relative to their width. Notice that the first band above the astragal is fifteen wide; draw the vertical line from the point A (section) to the point A (plan); draw the quarter circle A which intersects at E and F the lines of the rib. Take from the plan the width EF and lay it off from A to B along the curve on the section, thus obtaining the height of the first row of caissons. From the point B (section) draw a vertical to the (plan) and draw the quarter circle through B′ in plan intersecting the radii at G and H. This distance (G H) laid off along the curve from B to C shows the width of the second horizontal band. Now project the point C (section) to C′ (plan) and draw the quarter circle C′ on which C′ D′ will give the height of the second row of caissons which will be laid off from C to D along the curve in the section. Continue this operation up to the fifth row of caissons. As to the widths of the coffers, they are found on the plan of each row of caissons and consequently diminish gradually with them. The profile of the caissons is formed in the section in this way and their location is found in plan. From

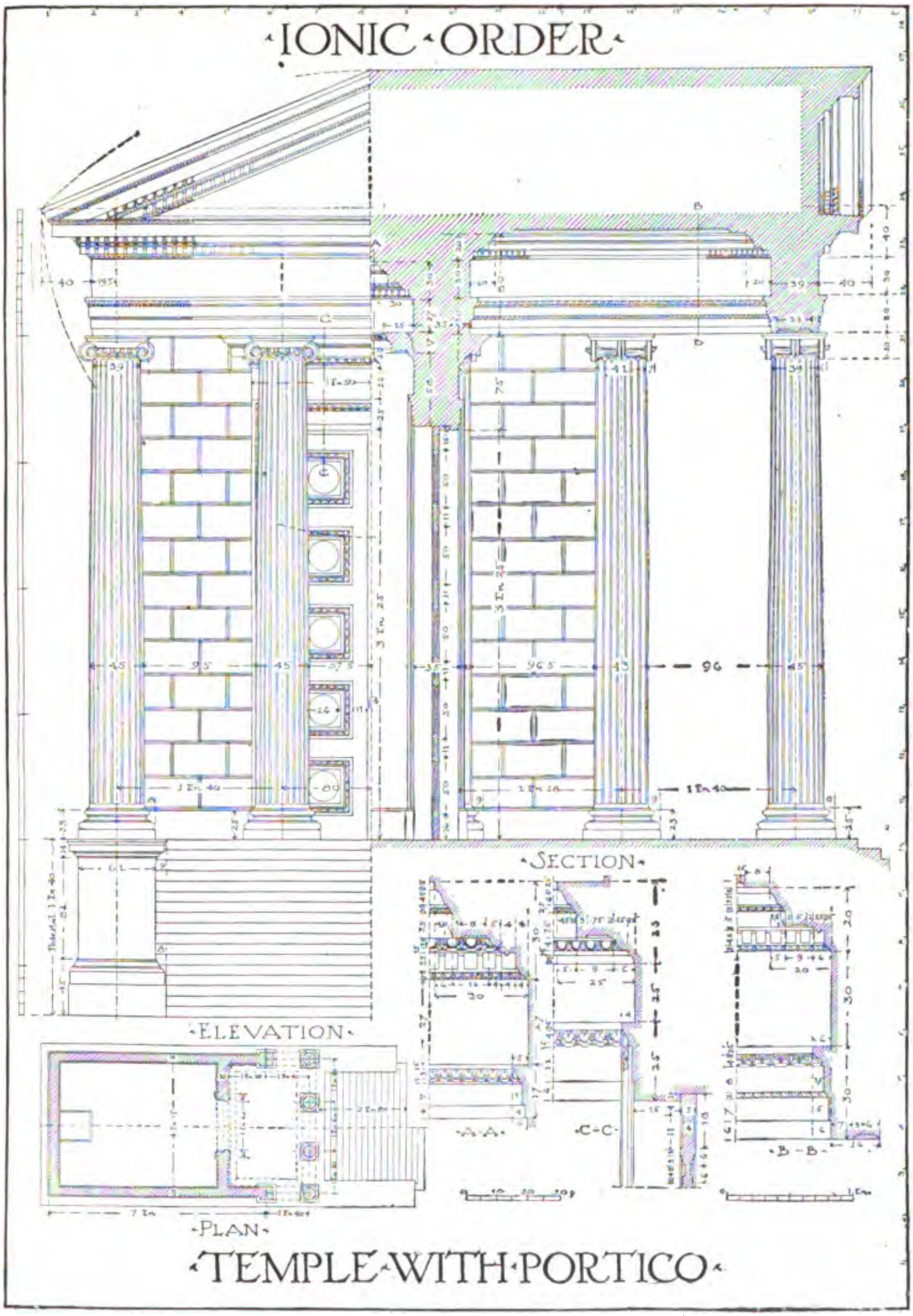


PLATE XXXIII.

(A reproduction at small size of Portfolio Plate XXXIII.)

each angle of the profile of the caisson draw a horizontal line through the section; this will give the horizontal lines on which all the points of intersection will be found in projecting the verticals from the corresponding points in the plan. Thus, from the point I (plan) which is found on the upper line of the topmost row of caissons, draw a vertical up to the point I (section) which is on the corresponding line in the section; from the point J (plan), which is found on the lower line of the same row of caissons, draw a vertical to the point J (section). Thus the circle I (plan) is represented in the section by the horizontal line I; the circle J, in the plan, by the horizontal J in section, the circles K, L, M, and N in plan by the horizontals K, L, M, and N of the section. The points of intersection of the radiating ribs in plan with the circular segment I, should be projected vertically to the horizontal I in the section. Those of the circle J, to the horizontal J; those of the circles K, L, M, and N, to the corresponding horizontals in the section. In this manner on each horizontal of the section, are found the points by means of which the curves of the bands may be drawn.

168. To draw the elevations of the stones of the circular part, it is necessary to show their location in plan, and, starting from the semi-pilaster which forms the junction of the portico with the circular walls, the stones are of the same length as those of the straight wall at the back of the portico. For the dentils of the circular cornice, the divisions in plan must also be made. The plan of this temple is shown in Fig. 29.

PLATE S.

169. In Plate XXXI is shown a temple that is entirely circular in plan and surrounded by a circular colonnade of Corinthian columns. The ceiling of the domed interior is similar to that of the building shown in Plate XXX, while the ceiling of the narrow porch outside the wall of the building is ornamented with coffers or panels, as is shown on the plan below. This temple is also to be drawn out to the size of 13×18 inches.

170. The axis of the colonnade is a circle of a radius of three entablatures and twenty parts, this circle being divided into twenty equal parts which give the spacing of the columns. The width of

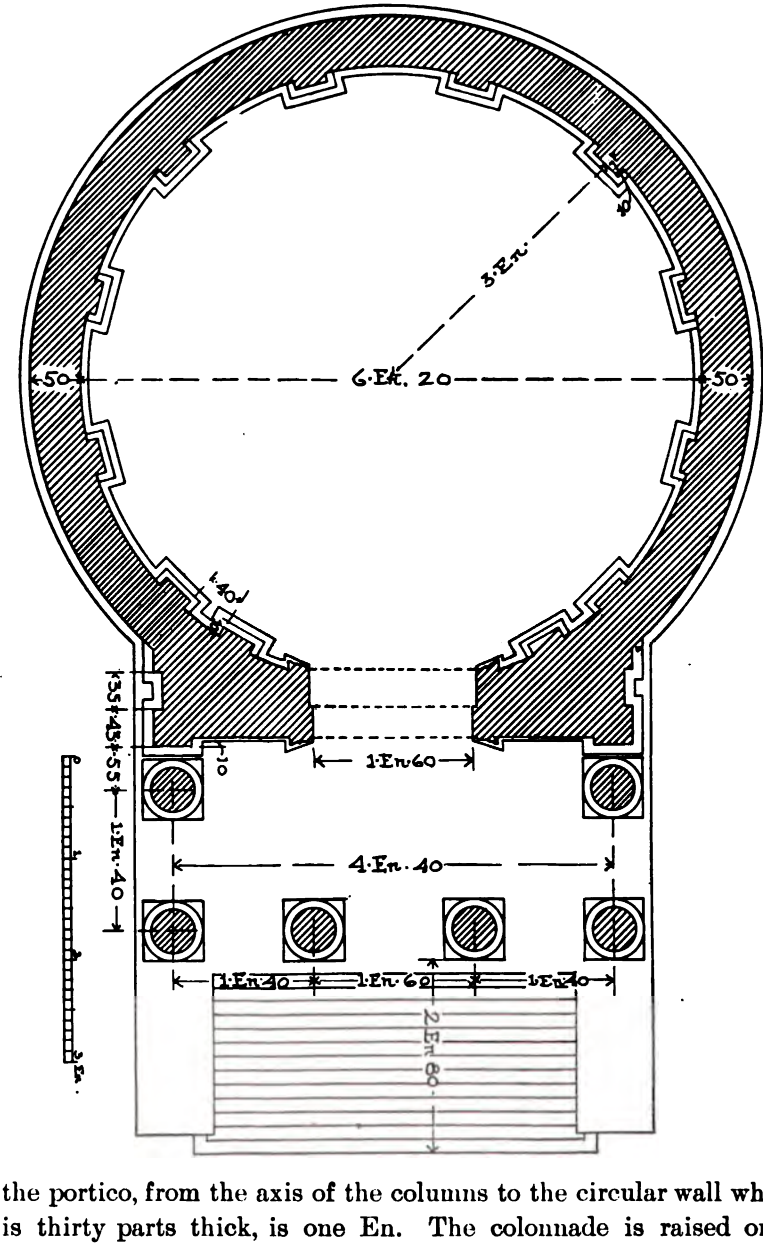


Fig. 29.

the portico, from the axis of the columns to the circular wall which is thirty parts thick, is one En. The colonnade is raised on a circular platform reached by seven steps, while the floor of the hall is raised one step above this level. The entrance to this hall

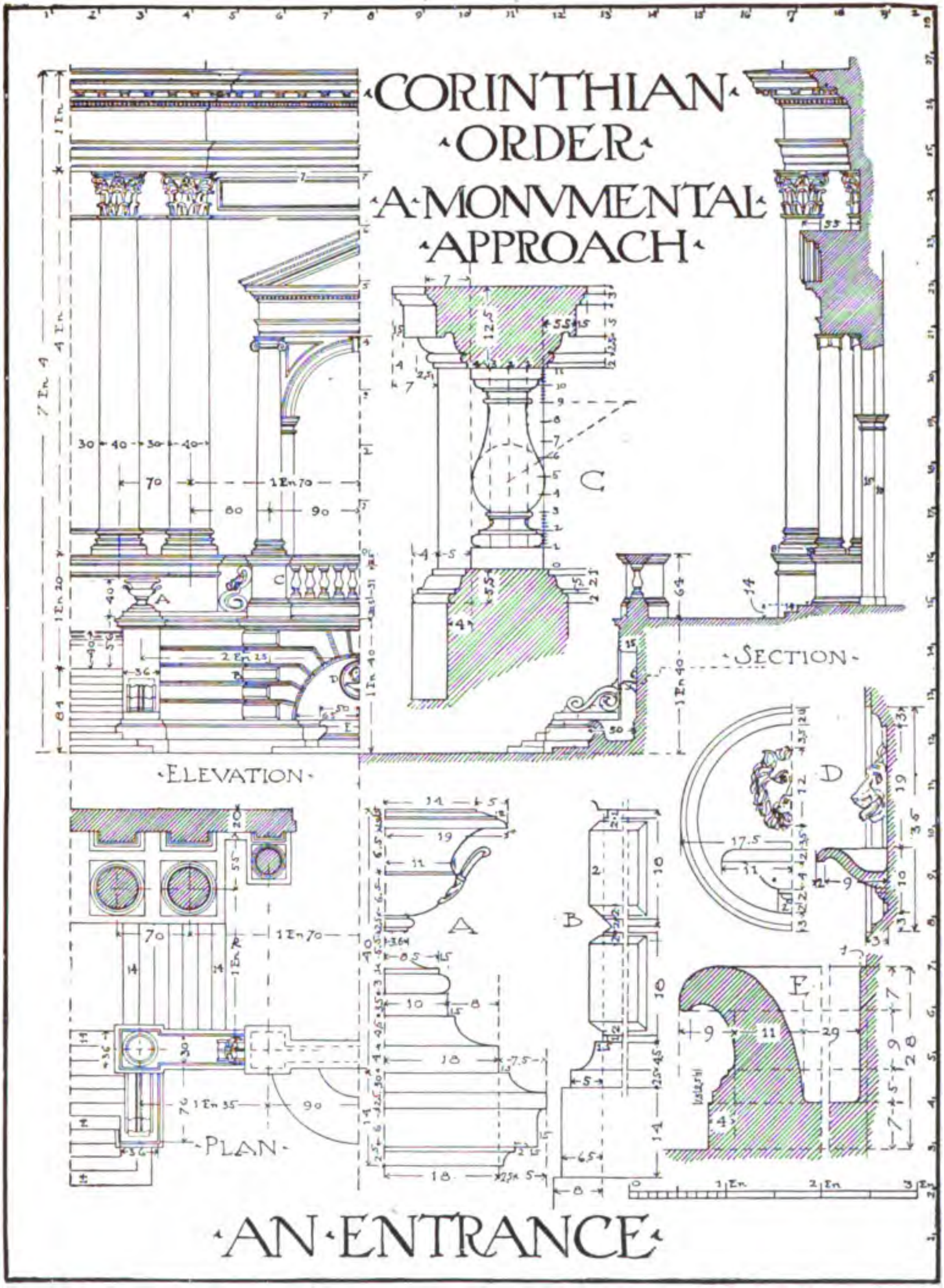


PLATE XXXIV.

(A reproduction at small size of Portfolio Plate XXXIV.)

is a doorway two entablatures seventy-nine parts in height by one entablature and twenty parts in width. Half of the plan shows the arrangement of the columns and shows that their capitals are placed square with the radii which pass through the columns. It will be necessary in drawing an elevation, to draw the plan of all the capitals since each one is seen in a different position, and it is only by means of the plan that the position of the details which make up the capital can be determined. Notice that the plinths of the bases, which, up to the present time have been square in plan, are here circular because their corners would partially block up the spaces between the columns. The other quarter of the plan shows the disposition of the ceiling of the portico, the soffit of the exterior cornice, and the caissons of the cupola.

171. The ceiling of the portico rests upon a small cornice and is divided into panels, which correspond to the columns and the spaces between the columns. In order to draw the caissons of the cupola, it will be necessary to repeat Plate R and go back to this study for the details of the lantern.

PLATE T.

172. In Plate XXXII is found a pavilion in the Mutular Doric Order. It is to be drawn with the border line of the same size as in the other plates, but, by omitting the plan here shown, it will be possible to increase the height of the building considerably and still bring it within the outlines of the drawing.

173. This small building is raised ten steps above the level of a garden, and is composed of a portico "in antis," giving access to the room beyond. The plan forms a square from center to center of the corner pilasters. This dimension corresponds to nine divisions, center to center, of the triglyphs in the entablature.

174. The four pilasters of the lateral facade form three regular bays of three spacings of the triglyphs. The intercolumniation in the center of the principal facade or portico is three entablatures, five times the distance from the center of one triglyph to the center of another, which is sixty parts, and the space between the antae and the columns is one entablature and twenty parts, or twice the distance between the triglyphs, center to center. The depth of the portico corresponds to one bay of the pilasters of the lateral facade, and the divisions of the pilasters of the rear facade correspond to the columns of the portico. In the middle of this rear facade is found a window which lights the interior; this window is twice its width in height and is placed above a wainscot of the height (1 En) shown in the section.

175. The entrance door is decorated with a frame similar to that in Plate XXV, and has an entablature with a pediment whose details are given on this plate at C. The entablature which surrounds the ceiling of the portico and of the hall is also the same as was used in Plate XXV.

176. The bases of wall and portico, and of the lateral and rear facades, are composed of a plain pedestal, or dado, one entablature in height, and with a rusticated part three entablatures high. "Rusticated" applies to masonry work in which the joints are strongly emphasized. The dado has a plinth base of a height corresponding to the height of the column base, and a cap fourteen parts high. The bead and congé of the bases continue around and above this plinth; the rusticated stones are alternately twenty-six and sixty-eight parts wide with sinkages of two parts.

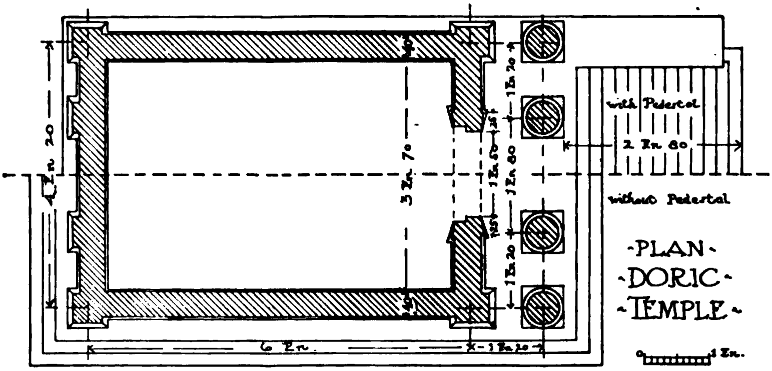


Fig. 30.

177. The roof is pyramidal in form and is crowned by a pineapple, of which the detail is given at D in this plate, XXXII, and the balustrade shown at the left-hand side of the facade would be the rail of a terrace on the edge of which this pavilion is located. This terrace, although the pavilion does not communicate with it, would be accessible by flights of steps placed laterally. For this the student may exercise his own imagination, and draw out separately at a smaller scale a plan giving his idea of the general arrangement.

PLATE U.

178. The facade of a Doric temple is to be drawn by the student from the plan shown in Fig. 30. The measurements necessary for the placing of the columns are here given, and further than this he is to supply their proper proportions and heights, as well as the necessary details, from the various drawings illustrating this order, which he has already studied. The four-columned portico on the front is crowned with a pediment, the proportions of which must be ascertained after the principle shown in Plates XXXII or XXXIII. This plate is to be drawn out with the border lines 20″×28″ in size.

179. The proportions and general scheme for laying out this problem will be found in the illustration of the Ionic Portico, Plate XXXIII. The various details both for the exterior entablature and for the entablature inside the temple, as well as the architraves for the entrance door, have already been given. The main facade or front elevation should be drawn to the center line which passes through the apex of the pediment and through the axis of the doorway. The section on this plate may be omitted, in which particular there will be a difference between this problem and the problem of the Ionic Order. In the plan it will be noticed that half has been shown with a pedestal, while the other half rests directly on a platform or "stylobate." It would be better to draw this order with a pedestal and to indicate by a dotted line the contour of the steps leading from the stylobate to the ground. The method of constructing the slope of the pediment has already been explained, and has also been shown on Plate XXXIII. This is essentially the same problem as that given under the Ionic Order, but the details and the proportions, it will be seen, are distinctly different.

PLATE V.

180. The Ionic Temple, with portico, shown in Plate XXXIII is to be drawn at the same size as the last plate, 20″×28″. These two drawings when finished should resemble each other, save that in the preceding exercise the full facade of the temple is shown, while in this plate of the Ionic Order a half facade and section are to be combined as illustrated.

181. The exterior face of the wall is formed with rusticated joints, that is to say, the joints of the stones form triangular recesses or grooves as shown at C, Plate XXIX. This decorative scheme is at the same time a logical construction because, the angles of the stones being obtuse, the edges are less liable to be broken off.

PLATE W.

182. This exercise is one of superposition and, as the same principle may be applied throughout the use of the other orders, it is believed that one drawing devoted to this subject will be amply sufficient. The student is required to reproduce the drawing shown in Fig. 23, at the size of 13″×18″ and to complete in his drawing all the details of the mouldings, windows, doorways, etc., where the same are only blocked in upon this figure. The considerations in regard to superposition, stated in the text in paragraphs 116 to 132, must be carefully observed.

PLATE X.

183. The subject of this study, Plate X, is the central part of the facade of an edifice; assume it is to be a library or public building of a similar character. The Corinthian Order is raised on a series of pedestals. The interior level of the edifice is raised above the exterior ground level and is reached by a staircase which will prove to be an interesting part of this study. This staircase is in two parts, each part composed of two flights with an intermediate landing. The first flight has twelve risers up to the landing; the second has eight risers up to the top of a wide landing which is placed before the entrance and on the axis of the edifice. A balustrade with two pedestals, on which might be placed statues or candelabras, surmounts the supporting wall of the landing. This supporting wall is finished on each side by a pillar on which is placed a vase, and is decorated with rusticated joints. The central part, corresponding to the balustrade, forms a projection; a niche decorated with a fountain and semi-circular basin would be practicable below this space. The entrance door of the edifice is in the form of an arch, covered with a pediment of the Ionic Order. The Corinthian columns forming the corners of the projection are coupled, that is to say, the space which separates them is less than the minimum of the regular intercolumniation.

184. The student is required to design, arrange and draw upon a plate, the size of 20″ × 28″, some such problem as is shown in Plate XXXIV, termed an Entrance or Monumental Approach. He may use any orders that he may choose for this problem, but should remember to maintain a proper relation between them in scale and size. He must not follow exactly this arrangement but must introduce such a variety in the plan as will give him a problem in elevation different from the one here solved.

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